#1

Application number: H04-235534
Date of filing: September 3, 1992
Publication number: H06-28455
Date of publication of application: February 4, 1994
Applicant: DAINIPPON PRINTING CO LTD
Inventor: Ueda, Tomoaki
Title of the Invention: Tomogram image processing method, organism magnetic field measuring method, organism magnetic field-measured outcome display method, and apparatus therefore

---

[Scope of the Claim]
[Claim 1]

A tomogram image processing method, comprising the steps of:

a) carrying out an interpolation operation on a plurality of tomogram images of a test boy sliced in an area at predetermined intervals to obtain stereoscopic image data elements;

b) dividing said area into small stereoscopic segments;

c) counting the number of said stereoscopic image data elements for each of said small stereoscopic segments; and

d) binarizing said small stereoscopic segments on the basis of the number of said stereoscopic image data elements.

[Claim 2]

A tomogram image processing apparatus, comprising:

interpolation carrying out means (3) for carrying out an interpolation operation on a plurality of tomogram images of a test boy sliced in an area at predetermined intervals to obtain stereoscopic image data elements;

area dividing means (7) for dividing said area into small stereoscopic segments;

stereoscopic image counting means (8) for counting the number of said stereoscopic image data elements for each of said small stereoscopic segments; and

binarizing means (9, 10) for binarizing said small stereoscopic segments on the basis of the number of said stereoscopic image data elements.

[Claim 3]

An organism magnetic field measuring method, comprising the steps of:

e) carrying out a plurality of Biot-Savart law calculations on a plurality of magnetic field information elements respectively for a plurality of vertexes of said small stereoscopic segments obtained in the tomogram image processing method as set forth in claim 1;

f) adding up the results of the Biot-Savart law calculations to obtain a calculated magnetic field value;

g) calculating a difference between said calculated magnetic field value and a measured magnetic field value;

h) correcting data on said magnetic field sources included in the results of the

Biot-Savart law calculations in accordance with said difference;

i) judging whether or not said difference is vanishingly small;

j) repeating said step (e) through step (h) when it is judged in said step (i) that said difference is not vanishingly small; and

k) outputting, as an organism magnetic field-measured outcome, said data on said magnetic field sources included in the results of the Biot-Savart law calculations carried out in said step (h) when it is judged in said step (i) that said difference is vanishingly small.

[Claim 4]

An organism magnetic field measuring method as set forth in claim 4, in which

said step (h) is replaced with the steps of:

h1) calculating a difference between a coordinate of each of said vertexes of said small stereoscopic segments and a coordinate of each of corrected vertexes of said small stereoscopic segments;

h2) calculating said coordinate of each of said corrected vertexes of said small stereoscopic segments on the basis of a code of said difference calculated in said step (h1); and

h3) redistributing an estimate value of said magnetic field source in accordance with said difference calculated in said step (h1) for each of said corrected vertexes of said small stereoscopic segments calculated in said step (h2).

[Claim 5]

An organism magnetic field measuring apparatus, comprising:

calculating means (111, 112, …., 11m; 101, 102, …., 10m) for carrying out a plurality of Biot-Savart law calculations on a plurality of magnetic field information elements respectively for a plurality of vertexes of said small stereoscopic segments obtained in the tomogram image processing method as set forth in claim 1;

adding means (20; 200) for adding up the results of the Biot-Savart law calculations outputted from said calculating means (111, 112, …., 11m; 101, 102, …., 10m) to obtain a calculated magnetic field value;

error calculating means (30; 300) for calculating a difference between said calculated magnetic field value outputted from said adding means (20; 200) and a measured magnetic field value;

correcting means (111a, 112a, …, 11ma) for correcting data on said magnetic field sources included the result of the Biot-Savart law calculations outputted from said calculating means (111, 112, …., 11m; 101, 102, …., 10m) in accordance with said difference; and

corrected result collecting means (40; 500) for collecting the results of the Biot-Savart law calculations corrected by said correcting means (111a, 112a, …, 11ma) and outputting them therethrough as an organism magnetic field-measured outcome.

[Claim 6]

An organism magnetic field measuring apparatus as set forth in claim 5, further comprising:

as correcting means, difference calculating means (41i) for calculating a difference between a coordinate of each of said vertexes of said small stereoscopic segments and a coordinate of each of corrected vertexes of said small stereoscopic segments;

corrected vertex extracting means (42i) for calculating said coordinate of each of said corrected vertexes of said small stereoscopic segments on the basis of a code of said difference calculated by said difference calculating means (41i); and

redistributing means (43i, 44i, 45i) for redistributing an estimate value of said magnetic field source in accordance with said difference calculated by said difference calculating means (41i) for each of said corrected vertexes of said small stereoscopic segments calculated by said corrected vertex extracting means (42i).

7. An organism magnetic field-measured outcome display method of displaying an organism magnetic field-measured outcome along with an organism structure reference image, comprising the steps of:

l) calculating absolute values of said organism magnetic field-measured outcomes for a plurality of vivo points;

m) setting up a size of a reference graphic for each of said vivo points on the basis of said absolute values calculated in said step (l); and

n) displaying said reference graphic whose sizes is set up in said step (m) along with said organism structure reference image for each of said vivo points.

8. An organism magnetic field-measured outcome display method of displaying an organism magnetic field-measured outcome as set forth in claim 7, in which said reference graphic is in the form of a circular shape.

9. An organism magnetic field-measured outcome display apparatus for displaying organism magnetic field-measured outcomes along with an organism structure reference image, comprising:

reference graphic size calculating means (700) for calculating absolute values of said organism magnetic field-measured outcomes for a plurality of vivo points, and setting up a size of a reference graphic for each of said vivo points on the basis of said absolute values thus calculated;

organism structure displaying means (800) for displaying said organism structure reference image; and

reference graphic displaying means (900) for displaying said reference graphic whose size is set up by said reference graphic size calculating means (700) for each of said vivo points.

10. An organism magnetic field-measured outcome display apparatus as set forth in claim 9, in which said reference graphic is in the form of a circular shape.

[Detailed Explanation of the Invention]

[0001]

[Industrial Field in which the Invention is Used]

The present invention relates to a tomogram image processing method, an organism magnetic field measuring method, an organism magnetic field-measured outcome display method, and apparatuses for carrying out the respective methods, and

more particularly, to a tomogram image processing method of and apparatus for obtaining fine image data based on tomogram images sliced at respective predetermined intervals, an organism magnetic field measuring method of and apparatus for analyzing an organism magnetic field source based on fine image data provided by the tomogram image processing method, and an organism magnetic field-measured outcome display method of and apparatus for displaying the analyzed outcome of the organism magnetic field source in an easily recognizable condition.

[0002]

[Description of the Prior Art]

There have been provided a wide variety of conventional methods for visually superimposing magnetic field sources on tomogram images such as for example MRI images in order to display an organism magnetic field-measured outcome in an easily recognizable condition. As a method of visually superimposing magnetic field sources on tomogram images have been proposed a method of two-dimensionally displaying the magnetic field source under the condition that the magnetic field source is superimposed on the closest tomogram image and a method of three-dimensionally displaying the magnetic field source under the condition that the magnetic field source is superimposed on a plurality of tomogram images.

[0003]

As methods of measuring an organism magnetic field there have been proposed two methods consisting of a first measuring method and a second measuring method. The first measuring method is to be carried out under an assumption that the magnetic field source has a single dipole, and the second measuring method is to be carried out under an assumption that the magnetic field source has a plurality of current elements. The first measuring method comprises the step of calculating the position and the direction of the single dipole based on a plurality of outcomes of magnetic fields measurement measured at a plurality of points in the vicinity of a body surface. The second measurement method comprises the steps of measuring a magnetic field assuming that the magnetic field source has a predetermined number of current elements (usually 10 to 100); detecting points at which the measured magnetic field is remarkably greater than the predetermined number of current elements; and calculating the position and the direction of the current elements by performing a computation at the detected points.

[0004]

Furthermore, as methods of displaying an outcome of a measured organism magnetic field, there are publicly known an arrow mapping display method and a contour mapping display method. The arrow mapping display method comprises the steps of measuring an organism magnetic field, analyzing a magnetic field based on the measured organism magnetic field to obtain a plurality of current elements, and displaying the current elements thus obtained in the form of a current vector. The contour mapping display method comprises the steps of displaying the measured organism magnetic field in the form of an isomagnetic line. Furthermore, in order to carry out such display methods in a medical diagnoses, it is also proposed to display

arrows indicative of the current vectors or the isomagnetic lines superimposed on the MRI pictorial images so as to visually represent the current elements or the isomagnetic lines in internal organs.

[0005]

[Problem(s) to be Solved by the Invention]

In the case that the two-dimensional display method in the abovementioned magnetic field source display methods is adopted, there is an inconvenience that it becomes very difficult for a medical doctor to recognize the position of the magnetic field source even though the medical doctor would carefully observe a plurality of the tomogram images by the reason that the tomogram image having the magnetic field source superimposed thereon is scarcely displayed. Moreover, although the tomogram image having the magnetic field source superimposed thereon should be selected and displayed, it is quite difficult to detect the relative position of the magnetic field source based on the selected tomogram image.

[0006]

Further, in the case that the three-dimensional display method in the abovementioned magnetic field source display methods is adopted, there is another inconvenience that it is very difficult to recognize how the magnetic field source is inwardly deep and widespread by the reason that there is no marks indicating the magnetic field except for the tomogram images. Moreover, it is also difficult to detect the position of the magnetic field relative to the internal organs because there are provided only a few tomogram images having the magnetic field superimposed thereon. In the case that the aforementioned first measuring method to be carried out under an assumption that the magnetic field source has a single dipole is adopted, there is further another inconvenience that the measured outcome is apt to converge on an excessively profound solution in addition to being not capable of measuring a distributive magnetic field source to be represented by a volume current flowing in the internal organ in pulsation by the reason that a single dipole is only obtained as the measured outcome.

[0007]

In the case that the aforementioned second measuring method to be carried out under an assumption that the magnetic field source includes a plurality of current elements is adopted, it becomes possible to measure the distributive magnetic field source. However, the fact that around 30-100 elements of currents are generally provided leads to the fact that it is required to calculate an estimate of each of current elements based on a plurality of magnetic field measuring values after setting up around 200-1000 channels of an array sensor and obtaining the plurality of magnetic field measuring values in the case that all of the current elements are to be measured. There is an inconvenience that the processing load to calculate the estimate in the abovementioned case requires T. FLOPS so that the system itself becomes considerably large in scale and cost. There is another inconvenience that the estimate thus calculated converges on the local minima, thereby remarkably aggravating the accuracy of the estimate of each of the current elements.

[0008]

Any of the abovementioned arrow mapping display method and the contour mapping display method is appropriate for visually displaying the organism magnetic field-measured value in a particular timing, in other words, for visually displaying an organism magnetic field-measured distribution. This means that the both of the abovementioned arrow mapping display method and the contour mapping display method are inappropriate for displaying the organism magnetic field-measuring value of internal organs in pulsation. More particularly, although it is possible to dynamically display current elements by means of the arrow map display method, a large number of the current elements in the internal organs must be set up in order to display the volume current. Thus, a remarkably large number of the current elements must be displayed. Further, there is an inconvenience that it is difficult to recognize, for example, the propagation status of a visceral excitation current even though an MRI pictorial image and an arrow in an overlap display are carefully observed since the direction and dimension of each of the current elements change from hour to hour.

[0009]

The contour mapping display method cannot be adopted for continuously displaying the organism magnetic field-measured value by the reason that the isomagnetic line is unsuitable for displaying each of the current elements. This leads to the fact that the contour map display method cannot be carried out to visualize the propagation status of the visceral excitation current.

[0010]

[Purpose of the Invention]

In order to solve the abovementioned problems, it is therefore a first object of the present invention to provide a tomogram image processing method and apparatus capable of obtaining fine image data based on fine tomogram image data of such as internal organs sliced at respective predetermined intervals, it is therefore a second object of the present invention to provide an organism magnetic field measuring method and apparatus capable of analyzing an organism magnetic field source easily and precisely based on the fine tomogram image data obtained by the tomogram image processing method, and it is therefore a third object of the present invention to provide an organism physical quantity-measured outcome display method and apparatus capable of continuously displaying the organism physical quantity-measured value in an easily recognizable condition.

[0011]

[Measures to Solve the Problems]

In order to achieve the abovementioned first object, there is provided a tomogram image processing method as set forth in claim 1, comprising the steps of: a) carrying out an interpolation operation on a plurality of tomogram images of a test boy sliced in an area at predetermined intervals to obtain stereoscopic image data elements; b) dividing said area into small stereoscopic segments; c) counting the number of said stereoscopic image data elements for each of said small stereoscopic segments; and d) binarizing said small stereoscopic segments on the basis of the number of said

stereoscopic image data elements.

[0012]

A tomogram image processing apparatus as set forth in claim 2, comprises: interpolation carrying out means (3) for carrying out an interpolation operation on a plurality of tomogram images of a test boy sliced in an area at predetermined intervals to obtain stereoscopic image data elements; area dividing means (7) for dividing said area into small stereoscopic segments; stereoscopic image counting means (8) for counting the number of said stereoscopic image data elements for each of said small stereoscopic segments; and binarizing means (9, 10) for binarizing said small stereoscopic segments on the basis of the number of said stereoscopic image data elements.

[0013]

In order to achieve the foregoing second object, there is provided an organism magnetic field measuring method as set forth in claim 3, comprising the steps of: e) carrying out a plurality of Biot-Savart law calculations on a plurality of magnetic field information elements respectively for a plurality of vertexes of said small stereoscopic segments obtained in the tomogram image processing method as set forth in claim 1; f) adding up the results of the Biot-Savart law calculations to obtain a calculated magnetic field value; g) calculating a difference between said calculated magnetic field value and a measured magnetic field value; h) correcting data on said magnetic field sources included in the results of the Biot-Savart law calculations in accordance with said difference; i) judging whether or not said difference is vanishingly small; j) repeating said step (e) through step (h) when it is judged in said step (i) that said difference is not vanishingly small; and k) outputting, as an organism magnetic field-measured outcome, said data on said magnetic field sources included in the results of the Biot-Savart law calculations carried out in said step (h) when it is judged in said step (i) that said difference is vanishingly small.

[0014]

In an organism magnetic field measuring method as set forth in claim 4, said step (h) is replaced with the steps of: h1) calculating a difference between a coordinate of each of said vertexes of said small stereoscopic segments and a coordinate of each of corrected vertexes of said small stereoscopic segments; h2) calculating said coordinate of each of said corrected vertexes of said small stereoscopic segments on the basis of a code of said difference calculated in said step (h1); and h3) redistributing an estimate value of said magnetic field source in accordance with said difference calculated in said step (h1) for each of said corrected vertexes of said small stereoscopic segments calculated in said step (h2).

[0015]

An organism magnetic field measuring apparatus as set forth in claim 5, comprises: calculating means (111, 112, …., 11m; 101, 102, …., 10m) for carrying out a plurality of Biot-Savart law calculations on a plurality of magnetic field information elements respectively for a plurality of vertexes of said small stereoscopic segments obtained in the tomogram image processing method as set forth in claim 1; adding

means (20; 200) for adding up the results of the Biot-Savart law calculations outputted from said calculating means (111, 112, ..., 11m; 101, 102, ..., 10m) to obtain a calculated magnetic field value; error calculating means (30; 300) for calculating a difference between said calculated magnetic field value outputted from said adding means (20; 200) and a measured magnetic field value; correcting means (111a, 112a, ..., 11ma) for correcting data on said magnetic field sources included the result of the Biot-Savart law calculations outputted from said calculating means (111, 112, ..., 11m; 101, 102, ..., 10m) in accordance with said difference; and corrected result collecting means (40; 500) for collecting the results of the Biot-Savart law calculations corrected by said correcting means (111a, 112a, ..., 11ma) and outputting them therethrough as an organism magnetic field-measured outcome.

[0016]

An organism magnetic field measuring apparatus as set forth in claim 6, further comprises: ,as correcting means, difference calculating means (41i) for calculating a difference between a coordinate of each of said vertexes of said small stereoscopic segments and a coordinate of each of corrected vertexes of said small stereoscopic segments; corrected vertex extracting means (42i) for calculating said coordinate of each of said corrected vertexes of said small stereoscopic segments on the basis of a code of said difference calculated by said difference calculating means (41i); and redistributing means (43i, 44i, 45i) for redistributing an estimate value of said magnetic field source in accordance with said difference calculated by said difference calculating means (41i) for each of said corrected vertexes of said small stereoscopic segments calculated by said corrected vertex extracting means (42i).

[0017]

In order to achieve the foregoing third object, there is provided a method as set forth in claim 7 of displaying an organism magnetic field-measured outcome along with an organism structure reference image, comprising the steps of: l) calculating absolute values of said organism magnetic field-measured outcomes for a plurality of vivo points; m) setting up a size of a reference graphic for each of said vivo points on the basis of said absolute values calculated in said step (l); and n) displaying said reference graphic whose sizes is set up in said step (m) along with said organism structure reference image for each of said vivo points. In a method of displaying an organism magnetic field-measured outcome as set forth in claim 8, said reference graphic is in the form of a circular shape.

[0018]

An organism magnetic field-measured outcome display apparatus as set forth in claim 9 for displaying organism magnetic field-measured outcomes along with an organism structure reference image, comprises: reference graphic size calculating means (700) for calculating absolute values of said organism magnetic field-measured outcomes for a plurality of vivo points, and setting up a size of a reference graphic for each of said vivo points on the basis of said absolute values thus calculated; organism structure displaying means (800) for displaying said organism structure reference image; and reference graphic displaying means (900) for displaying said reference

graphic whose size is set up by said reference graphic size calculating means (700) for each of said vivo points. In an organism magnetic field-measured outcome display apparatus as set forth in claim 10, said reference graphic is in the form of a circular shape.

[0019]

[Function]

A tomogram image processing method as set forth in claim 1, comprising the steps of: a) carrying out an interpolation operation on a plurality of tomogram images of a test boy sliced in an area at predetermined intervals to obtain stereoscopic image data elements; b) dividing said area into small stereoscopic segments; c) counting the number of said stereoscopic image data elements for each of said small stereoscopic segments; and d) binarizing said small stereoscopic segments on the basis of the number of said stereoscopic image data elements, can obtain the stereoscopic image data elements corresponding to all of the small stereoscopic segments by carrying out the interpolation operation on a plurality of tomogram images of the test body even through some tomogram images sliced at the intervals should fail to be provided. Further, the tomogram image processing method thus constructed can obtain a simplified stereoscopic image by the reason that the small stereoscopic segments are binarized on the basis of the number of the stereoscopic image data elements. This leads to the fact that the stereoscopic image obtained and displayed by the tomogram image processing method as set forth in claim 1 makes it possible for an operator to easily distinguish an area and/or a stereoscopic segment where an internal organ or the like is placed.

[0020]

Any of a linear interpolation arithmetical calculation, a spline interpolation arithmetical calculation, and the like may be appropriately selected and adopted for the abovementioned interpolation arithmetical operation. Further, an appropriate threshold value may be set up in order to adapt the numbers of the stereoscopic image data elements to be binarized to the numbers of the variety of the tomogram images and to the numbers of the internal organs to be processed. As a small stereoscopic segment, it is desirable to use a solid segment with which the segment can be filled densely. It more preferable to use a cube segment in order to simplify the treatments later performed.

[0021]

A tomogram image processing apparatus as set forth in claim 2, comprises: interpolation carrying out means (3) for carrying out an interpolation operation on a plurality of tomogram images of a test boy sliced in an area at predetermined intervals to obtain stereoscopic image data elements; area dividing means (7) for dividing said area into small stereoscopic segments; stereoscopic image counting means (8) for counting the number of said stereoscopic image data elements for each of said small stereoscopic segments; and binarizing means (9, 10) for binarizing said small stereoscopic segments on the basis of the number of said stereoscopic image data elements. The stereoscopic image obtained and displayed by the tomogram image

processing apparatus thus constructed makes it possible for an operator to easily distinguish an area and/or a stereoscopic segment where an internal organ or the like is placed. The organism magnetic field measuring method as set forth in claim 3, comprising the steps of: e) carrying out a plurality of Biot-Savart law calculations on a plurality of magnetic field information elements respectively for a plurality of vertexes of said small stereoscopic segments obtained in the tomogram image processing method as set forth in claim 1; f) adding up the results of the Biot-Savart law calculations to obtain a calculated magnetic field value; g) calculating a difference between said calculated magnetic field value and a measured magnetic field value; h) correcting data on said magnetic field sources included in the results of the Biot-Savart law calculations in accordance with said difference; i) judging whether or not said difference is vanishingly small; j) repeating said step (e) through step (h) when it is judged in said step (i) that said difference is not vanishingly small; and k) outputting, as an organism magnetic field-measured outcome, said data on said magnetic field sources included in the results of the Biot-Savart law calculations carried out in said step (h) when it is judged in said step (i) that said difference is vanishingly small, can obtain the data on the magnetic field source for each of a plurality of vertexes of said small stereoscopic segments by the reason that data on said magnetic field sources included in the results of the Biot-Savart law calculations is corrected until the difference between said calculated magnetic field value and a measured magnetic field value becomes vanishingly small. Furthermore, the number of unknown factors to be estimated can be largely reduced by the reason that the position of each of the vertexes of the small stereoscopic segments is known.

[0022]

The organism magnetic field measuring method as set forth in claim 4, in which said step (h) is replaced with the steps of: h1) calculating a difference between a coordinate of each of said vertexes of said small stereoscopic segments and a coordinate of each of corrected vertexes of said small stereoscopic segments; h2) calculating said coordinate of each of said corrected vertexes of said small stereoscopic segments on the basis of a code of said difference calculated in said step (h1); and h3) redistributing an estimate value of said magnetic field source in accordance with said difference calculated in said step (h1) for each of said corrected vertexes of said small stereoscopic segments calculated in said step (h2), can obtain accurate information on the magnetic field source by the reason that even magnetic field source vectors assigned in positions adjoining to each other, equal to each other in magnitude but opposing to each other in direction can be calibrated.

[0023]

In the organism magnetic field measuring apparatus as set forth in claim 5, the calculating means is operative to carry out a plurality of Biot-Savart law calculations on a plurality of magnetic field information elements respectively for a plurality of vertexes of said small stereoscopic segments obtained in the tomogram image processing method as set forth in claim 1, and the adding means is operative to add up the results of the Biot-Savart law calculations outputted from said calculating means to

obtain a calculated magnetic field value. The error calculating means is operative to calculate a difference between said calculated magnetic field value outputted from said adding means and a measured magnetic field value, and the correcting means is operative to correct data on said magnetic field sources included the result of the Biot-Savart law calculations outputted from said calculating means in accordance with said difference. After the correcting means has corrected the data on the magnetic field sources, the corrected result collecting means is operative to collect the results of the Biot-Savart law calculations thus corrected output them therethrough as an organism magnetic field-measured outcome. The organism magnetic field measuring apparatus thus constructed makes it possible for an operator to obtain the data on the magnetic field source for each of the vertexes of the small stereoscopic segments. Furthermore, the number of unknown factors to be estimated can be largely reduced by the reason that the position of each of the vertexes of the small stereoscopic segments is known.

[0024]

An organism magnetic field measuring apparatus as set forth in claim 6, further comprises: ,as correcting means, difference calculating means (41i) for calculating a difference between a coordinate of each of said vertexes of said small stereoscopic segments and a coordinate of each of corrected vertexes of said small stereoscopic segments; corrected vertex extracting means (42i) for calculating said coordinate of each of said corrected vertexes of said small stereoscopic segments on the basis of a code of said difference calculated by said difference calculating means (41i); and redistributing means (43i, 44i, 45i) for redistributing an estimate value of said magnetic field source in accordance with said difference calculated by said difference calculating means (41i) for each of said corrected vertexes of said small stereoscopic segments calculated by said corrected vertex extracting means (42i), can obtain accurate information on the magnetic field source by the reason that even magnetic field source vectors assigned in positions adjoining to each other, equal to each other in magnitude but opposing to each other in direction can be calibrated.

[0025]

The organism magnetic field measuring method will be described in detail hereinlater. As a result of enormous researches made by the inventor of the present invention in the field of measuring the organism magnetic field, it is found out that the position of each of the vertexes of the small stereoscopic segments is known because of the fact that each of the vertexes of the small stereoscopic segments has been obtained by the tomogram image processing method. This leads to the fact that information required to obtain the information on the magnetic field source is a vector component of the current element only.

[0026]

Even if the number of the small stereoscopic segments increases, the number of the vertexes does not increase in proportion to the increased number of the small stereoscopic segments by the reason that one vertex of one small stereoscopic segment serves as the vertex of the adjacent small stereoscopic segment. In the case that the

number of the small stereoscopic segments is large enough, the number of the vertexes and the number of the small stereoscopic segments are approximately equal to each other. By the fact that a current element of one vertex is related to that of an adjacent vertex, the amount of data of the current element of one vertex can be reduced remarkably, compared to the case that a general unknown quantity is estimated.
[0027]

The number of current elements to be finally estimated is remarkably small by the reason that the current element of a vertex having no magnetic field source converges on a zero vector. The inventions defined in claims 3 through 6 are made based on the abovementioned knowledge. A predetermined number of the magnetic field measuring values are obtained based on the efficiency and the capacity of the measuring system without considering an unknown number of current elements when the unknown current elements [the number is unknown either] are estimated at the start of measuring. A precise estimate of the unknown current elements can be achieved by repeating the correcting process of the data of the magnetic field source based on the predetermined number of the magnetic field measuring values, and the estimate outcome of which can be adopted as an organism magnetic field measured outcome.
[0028]

The organism magnetic field-measured outcome display method as set forth in claim 7 of displaying an organism magnetic field-measured outcome along with an organism structure reference image, comprising the steps of: l) calculating absolute values of said organism magnetic field-measured outcomes for a plurality of vivo points; m) setting up a size of a reference graphic for each of said vivo points on the basis of said absolute values calculated in said step (l); and n) displaying said reference graphic whose sizes is set up in said step (m) along with said organism structure reference image for each of said vivo points, makes it possible for an operator to recognize, for example, the distributed condition of the maximal organism magnetic field-measured outcome in comparison with the case that the magnetic field measured outcome is displayed with the direction and the length of the arrows. The direction components of the organism magnetic field cannot be recognized. It is, however, not inconvenient by the reason that the organism magnetic field measured outcome can be dynamically displayed, thereby making it possible for an operator to easily recognize, for example, the time-variant fluctuation of the distributed condition of the maximal organism magnetic field measured outcome. The organism magnetic field-measured outcome display method thus constructed can satisfy the requirement of the medical analysis that the distribution of the maximal organism magnetic field-measured outcome and the time-variant fluctuation should be represented in an easily understandable manner. This leads to the fact that the organism magnetic field-measured outcome display method thus constructed is most appropriate for the medical analysis.
[0029]

In the organism magnetic field-measured outcome display method as set forth in claim 8, said reference graphic is in the form of a circular shape. In addition to the

operations as set forth in claim 7 the magnetic field-measured outcome display method as set forth in claim 8 can considerably enlarge a clearance between the reference graphics, thereby making it possible for an operator to recognize the organism structure reference image as a background. The organism magnetic field-measured outcome display apparatus as set forth in claim 9 is operative to display organism magnetic field-measured outcomes along with an organism structure reference image in a manner that the reference graphic size calculating means is operative to calculate the absolute values of said organism magnetic field-measured outcomes for a plurality of vivo points, and setting up a size of a reference graphic for each of said vivo points on the basis of said absolute values thus calculated, the organism structure displaying means is operative to display said organism structure reference image; and the reference graphic displaying means is operative to display said reference graphic whose size is set up by said reference graphic size calculating means for each of said vivo points. The organism magnetic field-measured outcome display apparatus thus constructed makes it possible for an operator to recognize, for example, the distributed condition of the maximal organism magnetic field-measured outcome in comparison with the case that the magnetic field measured outcome is displayed with the direction and the length of the arrows. The direction components of the organism magnetic field cannot be recognized. It is, however, not inconvenient by the reason that the organism magnetic field measured outcome can be dynamically displayed, thereby making it possible for an operator to easily recognize, for example, the time-variant fluctuation of the distributed condition of the maximal organism magnetic field measured outcome. The organism magnetic field-measured outcome display apparatus thus constructed can satisfy the requirement of the medical analysis that the distribution of the maximal organism magnetic field-measured outcome and the time-variant fluctuation should be represented in an easily understandable manner. This leads to the fact that the organism magnetic field-measured outcome display apparatus thus constructed is most appropriate for the medical analysis.

[0030]

In the organism magnetic field-measured outcome display apparatus as set forth in claim 10, said reference graphic is in the form of a circular shape. In addition to the operations as set forth in claim 9 the magnetic field-measured outcome display apparatus as set forth in claim 10 can considerably enlarge a clearance between reference graphics, thereby making it possible for an operator to recognize the organism structure reference image as a background.

[0031]

[EMBODIMENT OF THE PRESENT INVENTION]

Preferred embodiments of the tomogram image processing method, the organism magnetic field measuring method, the organism magnetic field-measured outcome display method, and the apparatuses for the respective methods according to the present invention will now be described in detail in accordance with accompanying drawings. Referring now to the drawings, in particular to FIG. 1 of a flowchart, there is shown a preferred embodiment of the tomogram image processing method according

to the present invention. The tomogram image processing method comprises the steps of: waiting for receiving a plurality of tomogram images of a test boy sliced in an area at predetermined intervals (step SP 1); carrying out an interpolation operation on the plurality of received tomogram images to obtain interpolated tomogram images (step SP2); quantizing the received tomogram images and the interpolated tomogram images to obtain a plurality of squares each having a predetermined size (step SP3); dividing the area into a plurality of small stereoscopic segments each in the form of a cube shape having a center axis passing through the center of and a side equal in length to the side of the square (step SP4); counting the number of pixels constituting the received tomogram images and the interpolated tomogram images for each of the small stereoscopic segments (step SP5); judging whether or not the counted number is larger than a predetermined threshold value (for example, the average of all of the averages) for each of the small stereoscopic segments (step SP6), assigning each of the small stereoscopic segments, for which the counted number is judged in the step of SP6 to be larger than the threshold value, to "a small stereoscopic segment group to be displayed" (step SP7), and assigning each of the small stereoscopic segments , for which the counted number is judged in the step of SP7 to be not larger than the threshold value, to "a small stereoscopic segment group to be not displayed" (step SP8). The tomogram image processing method further comprises the steps of judging whether or not the step SP7 or the step SP8 has been performed for all of the small stereoscopic segments (step SP9). When it is judged in the step of SP9 that the step SP7 or the step SP8 has not been performed for a small stereoscopic segment, the step SP9 goes forward to the step SP10, in which the small stereoscopic segment is selected, and the step SP10 goes back to the step SP5. When it is judged in the step of SP9 that the step SP7 or the step SP8 has been performed for all of the small stereoscopic segment, the step SP9 goes forward to the step SP11, in which each of the small stereoscopic segments assigned to the small stereoscopic segment group to be displayed is visually displayed.

[0032]

It is needless to mention to the ratio of the number of pixels constituting the tomogram images to the number of pixels contained in a small stereoscopic segment for each of the small stereoscopic segments and a corresponding threshold value can be adopted in place of the number of pixels contained for each of the small stereoscopic segments. The present embodiment of the tomogram image processing method will be described in detail with reference to the drawings, in particular to FIGS. 2 through 4. FIG. 2 is a schematic diagram showing an example of a tomogram image, wherein the parts that are painted out indicates an internal organ of a human body. The tomogram image shown in FIG. 2 is constituted by a plurality of squares. As shown in FIG. 2, the center of each of the squares is shown with a small dot. This leads to the fact that a plurality of small stereoscopic segments each in the form of a cube shape having a center axis passing through the center of the square shown by the dot can be determined. As shown in FIG. 3, the small stereoscopic segments each having the number of pixels larger than a predetermined threshold value are assigned to the "small

stereoscopic segment group to be displayed" and the small stereoscopic segments each having the number of pixels not larger than a predetermined threshold value are assigned to the "small stereoscopic segment group to be not displayed". FIG. 4 is a perspective view corresponding to FIG. 3, and only the small stereoscopic segments assigned to the "small stereoscopic segment group to be displayed" is displayed. As will be seen in FIG. 4, the displayed small stereoscopic segments make it possible for an operator to visually recognize an internal organ.

[0033]

As will be understood from the foregoing description, carrying out a series of above-mentioned processes on all of the received tomogram images and the interpolated tomogram images makes it possible to visually display the organism internal organs as a solid model. It is, however, desirable to semi-transparently display the small stereoscopic segments assigned to the "small stereoscopic segment group to be displayed" so that the magnetic field source analyzing outcome can be easily recognized when a magnetic field source analyzing outcome is superimposed and displayed. Furthermore, specifying respective internal organs contained in the tomogram images makes it possible to display only the internal organs to be inspected or to display a plurality of the internal organs with their own colors. When an organism magnetic field source or the like, which will be described later, is analyzed, the tomogram image processing method according to the present invention thus constructed can process only the small stereoscopic segments assigned to the "small stereoscopic segment group to be displayed", thereby largely reducing arithmetical calculations required for the post processing by the reason that the small stereoscopic segments assigned to the "small stereoscopic segment group to be not displayed" correspond to a visceral cavity or the like and are accordingly ignored.

[0034]

[Second Embodiment]

Referring to the drawings, in particular to FIG. 5 of a block diagram, there is shown a second embodiment of the tomogram image processing apparatus according to the present invention. The tomogram image processing apparatus, comprises: a tomogram image storing unit 1 for storing therein a plurality of tomogram images, a first tomogram image selecting unit 2 for selecting a tomogram image to be processed among the tomogram images stored in the tomogram image storing unit 1, an interpolation carrying out unit 3 for carrying out an interpolation operation on the basis of the tomogram images selected by the first tomogram image selecting unit 2 to obtain interpolated tomogram images, an interpolation tomogram image storing unit 4 for storing the interpolated tomogram images obtained by the interpolation carrying out unit 3, a first repeat control unit 5 for having the tomogram image selecting unit 2 and the tomogram image interpolating unit 3 repeatedly operate for a necessary number of times, a second tomogram image selecting unit 6 for sequentially selecting a tomogram image from among the tomogram images stored in the tomogram image storing unit 1 or the interpolation tomogram image storing unit 4 in response to an end signal indicative of the end of the repeat control operation of the first repeat control unit 5, a

stereoscopic segment assigning unit 7 for assigning the tomogram image selected by the second tomogram image selecting unit 6 to a stereoscopic segment, a pixel number counting unit 8 for counting the number of pixels present in the stereoscopic segment, a judging unit 9 for judging whether or not the number of pixels counted by the pixel number counting unit 8 is larger than a predetermined threshold value, a display-stereoscopic segment assigning unit 10 for assigning the small stereoscopic segment, for which the counted number is judged by the judging unit 8 to be larger than the threshold value, to "a small stereoscopic segment group to be displayed", a non-display-stereoscopic segment assigning unit 11 for assigning the small stereoscopic segment, for which the counted number is judged by the judging unit 8 to be not larger than the threshold value, to "a small stereoscopic segment group to be not displayed", an assigning outcome storing unit 12 for storing therein the received tomogram images and the interpolated tomogram images in association with the small stereoscopic segments assigned to the respective small stereoscopic segment groups, a second repeat control unit 13 for controlling the second tomogram image selecting unit 6, the stereoscopic segment assigning unit 7, the pixel counting unit 8, the judging unit 9, the display-stereoscopic segment assigning unit 10 and the non-displaying assigning unit 11 to have the second tomogram image selecting unit 6, the stereoscopic segment assigning unit 7, the pixel counting unit 8, the judging unit 9, the display-stereoscopic segment assigning unit 10 and the non-displaying assigning unit 11 repeatedly operate for a necessary number of times, and a stereoscopic segment displaying unit 14 for visually displaying only the small stereoscopic segments assigned to the "small stereoscopic segment group to be displayed" in response to an end signal indicative of the end of the repeat control operation of the second repeat control unit 13.

[0035]

As will be seen from the foregoing description, it is to be understood that the tomogram processing apparatus according to the present invention thus constructed as shown in FIG. 5 can perform processing on the tomogram images as shown in FIGS. 2 through 4, and thus visually display only the small stereoscopic segments assigned to the "small stereoscopic segment group to be displayed".

[0036]

[Third Embodiment]

Referring to the drawings, in particular to FIG. 6 of a block diagram, there is shown a third preferred embodiment of the organism magnetic field measuring apparatus according to the present invention. The organism magnetic field measuring apparatus is shown in FIG. 6 as comprising: a plurality of Biot-Savart arithmetical calculating units 111, 112, ... ,11m each for carrying out a Biot-Savart law calculation on a magnetic field information element for a vertex of the small stereoscopic segment obtained in the tomogram image processing method shown in FIG. 1 or the tomogram image processing apparatus shown in FIG. 5, an adding unit 20 for adding up the results of the Biot-Savart law calculations outputted from the Biot-Savart arithmetical calculating unit 111, 112, ..., 11m; 101, 102, ..., an error calculator 30 for calculating a difference between an added-up value Oj(t) outputted from the adding unit 20 and a

magnetic field-measured value Sj(t) inputted as a teacher pattern, a plurality of correcting units 111a,112a, ..., 11ma respectively for correcting vector components of current elements estimated by the Biot-Savart arithmetical calculating units 111, 112, ..., 11m based on the difference calculated by the error calculator 30, and a data collecting unit 40 for collecting the vector components of the current elements estimated by the Biot-Savart arithmetical calculating units 111, 112, ..., 11m and to output the vector components thus collected as an analyzing outcome. Furthermore, each of the Biot-Savart arithmetical calculating units 111, 112, ... ,11m is adapted to carry out a Biot-Savart law calculation on a magnetic field information element for a vertex of the small stereoscopic segment obtained at time "t" in the tomogram image processing method shown in FIG. 1 or by the tomogram image processing apparatus shown in FIG. 5, and correct the vector components of the estimated current elements in response to the difference dj(t) = {Sj(t) – Oj(t)} calculated by the error calculator 30. The operations of the Biot-Savart arithmetical calculating units 111, 112, ... ,11m may be performed synchronously or asynchronously.

[0037]

The operation of the organism magnetic field measuring apparatus thus constructed will be described hereinlater. Magnetic field Oj(t) to be analyzed is represented by the linear sum of the time "t", three-dimensional coordinate values xi, yi, zi (" i" is intended to mean a positive integer) of each vertex of the respective small stereoscopic segments, and functions gi (each of the functions is determined based on the Biot-Savart law). Each of the functions gi has vector components Pxi, Pyi, Pzi of the current elements. When only vector components on a plane are used as measurable components for a magnetic field sensor, any of the vector components can be omitted by applying the coordinates to the sensor. All of the three-dimensional coordinate values are known by the fact that the respective small stereoscopic segments are provided by the tomogram image processing method of FIG. 1 or the tomogram processing apparatus of FIG. 5.

[0038]

Accordingly, the organism magnetic field measuring apparatus thus constructed can obtain the added-up value Oj(t) with the processes of: supplying "m" unit of the Biot-Savart arithmetical calculating units 111, 112, ... , 11m with the time "t" and the three-dimensional coordinate values of each of the vertexes of the respective small stereoscopic segments; performing the arithmetical calculation g1, g2, ..., gm respectively to calculate the function values, and supplying the adding unit 20 with all of the calculated values. The added-up value O j (t) provided on the first iteration of the above-mentioned processes is however different from the actual measured value S j (t) by the reason that the vector components of the respective current elements are set up at arbitrary numbers on the first iteration. The error calculator 30 is then operated to calculate a difference between actual measured value Sj(t) and the added-up value O j (t), and feed the difference thus calculated as an estimated error dj (t) back to the respective correcting units 111a, 112a, ... , 11ma so that the Biot-Savart arithmetical calculating units 111, 112, ... , 11m will alter the

vector components of the respective Biot-Savart arithmetical calculating units until the estimated error dj (t) becomes small.

[0039]

The above-mentioned processes are repeated until the estimated error dj (t) becomes approximately zero. The data collecting unit 40 is then operated to collect the vector components of the current elements estimated by the Biot-Savart arithmetical calculating units 111, 112, ..., 11m and to output the vector components thus collected as an analyzing outcome. The vector component of the current element in each of the vertexes of the respective small stereoscopic segments can be outputted from the data collecting unit 40 at this stage. Further, an estimated error evaluating function Ej (t) is defined by the formula: $Ej(t) = (1/2)\{Sj(t) - 0j(t)\}^2$, Equation 1 is obtained as follows.

[Equation 1]

$$\partial Ej(t)/\partial 0j(t) = -[Sj(t) - 0j(t)]$$

[0041]

If the vector component estimated by each of the Biot-Savart arithmetical calculating units is corrected based on a steepest descent method, the vector component, which minimizes the value of the estimated error evaluating function, can be obtained in accordance with the following Equation 2. Here, εk is a learning gain (a correcting gain) of the vector component aik.

[0042]

[Equation 2]

$$aik = aik - \varepsilon k\{\partial Ej(t)/\partial aik\}$$
$$= aik - \varepsilon k\{(\partial Ej(t)/\partial 0j(t))\{\partial 0j(t)/\partial aik\} = aik + \varepsilon k\{Sj(t) - 0j(t)\}\{\partial 0j(t)/\partial aik\}$$

[0043]

The equation 2 can be expressed with the equation 4 by the reason that the partial differential value with aik of the added-up value O j (t) is given in accordance with the equation 3.

[0044]

[Equation 3]

$$\partial 0j(t)/\partial aik = \partial\{\sum_{i=1}^{m} gi(t, ai1, ai2, ai3, \cdots aiL)\}/\partial aik$$
$$= \partial\{gi(t, ai1, ai2, ai3, \cdots aiL)\}/\partial aik$$

[0045]

[Equation 4]

$$aik = aik + \varepsilon k\{Sj(t) - 0j(t)\}[\partial\{gi(t, ai1, ai2, ai3, \cdots aiL)\}/\partial aik]$$

[0046]

From the foregoing description, it is to be understood that the second preferred embodiment of the present invention, which carries out the operation in accordance with Equation 4, can thus improve the accuracy of the estimated vector components. In addition, the corrected value may be set at a negative value when the gradient of the estimated error dj(t) is positive, and may be set at a positive value when the gradient of the estimated error dj(t) is negative. When the vector component of the current element of each vertex is thus obtained, a vector space interpolation processing is carried out based on the current elements of eight vertexes, a magnetic flux density where a minute point occurs is obtained, the magnetic flux density where each of the minute points occurs is integrated, and a magnetic field of each of the small stereoscopic segments is then obtained. Thus, the distributed currents can be displayed with fogs or arrows based on the provided outcome.

[0047]

Furthermore, the process performed by the apparatus shown in FIG. 6 is applicable only to the small stereoscopic segments assigned to the "small stereoscopic segment group to be displayed" obtained by the embodiment shown in FIG. 1 or FIG. 5, thereby largely reducing arithmetical calculations by the reason that the small stereoscopic segments assigned to the "small stereoscopic segment group to be not displayed" correspond to a visceral cavity or the like and are accordingly ignored. Moreover, even if the number of the small stereoscopic segments increases, the number of the vertexes does not increase in proportion to the increased number of the small stereoscopic segments by the reason that one vertex of one small stereoscopic segment serves as the vertex of the adjacent small stereoscopic segment. In the case that the number of the small stereoscopic segments is large enough, the number of the vertexes and the number of the small stereoscopic segments are approximately equal to each other. This also leads to the fact that the present embodiment can reduce the operation load.

[0048]

According to the present invention, the vector components can be sufficiently estimated with a comparatively small number of the measuring points although it has been generally believed that the number of measuring points is required to be greater than the number of unknown values in order to obtain unknown magnetic field-measured values. This also leads to the fact that the present embodiment can degrease the number of measuring points, thereby as a whole reducing the operation load.

[0049]

The following description will be directed to the above-mentioned aspect in detail. Conventionally, internal organs has not been defined as aggregations of small stereoscopic segments, and, for example, the number of measuring points is required to be not less than the number of the current elements to be estimated. This results in the fact that number of the measuring points tends to be more than required especially when the number of the current elements is unknown. The number of the current

elements could not but become enormous by the reason that the currents flowing in the internal organs vary in position, direction, and absolute value with the course of time. In the present embodiment, on the other hand, since the position of each of the small stereoscopic segments is fixed in advance; the current element for a small stereoscopic segment, which does not influence the measuring point, converges on a zero vector. The current element, which has converged on the zero vector, is not required to be processed later. This leads to the fact that the present embodiment of the organism magnetic field measuring apparatus can accurately estimate the vector components based on magnetic field-measured values obtained at a relatively small number of measuring points.

[0050]

Referring now to the drawings, in particular to FIG. 7 of a block diagram, there is shown another preferred embodiment of the organism magnetic field measuring apparatus according to the present invention, and in particular to FIG. 8 of a schematic diagram, there is shown a detailed construction of a part corresponding to a hierarchical type perceptron. The present embodiment of the organism magnetic field measuring apparatus is as shown in FIGS. 7 and 8 comprising: a plurality of hierarchical type perceptrons 10p (p=1,2, ... ,m) each having a plurality of inputs terminals and one output terminal, an adding unit 200 for adding up function values gij outputted from the respective hierarchical type perceptrons 10p, a function value error calculator 300 for calculating a difference between the added-up outcome Oj(t) outputted from the adding unit 200 and a measuring value Sj(t) inputted as a teacher pattern, a plurality of partial differential value calculating units 10pr (r=1,2, ... n) each for calculating a partial differential value corresponding to the function value gij outputted from the hierarchical type perceptron 10p, a partial differential value error calculator 30pr each for calculating a difference between an output from the partial differential value calculating unit 10pr of the hierarchical type perceptron 10p and a partial differential value (a partial differential value teacher pattern) calculated in advance in accordance with the numerical differentiation method, a partial differential function learning unit 60p each for having the applicable hierarchical type perceptron 10p learn a partial differential function based on the difference calculated by the function value error calculator 300 and the difference calculated by the partial differential value error calculator 30pr, a plurality of correcting units 12p each for correcting data to be inputted into the input layer of the hierarchical type perceptron 10p (hereinlater referred to as "input data of the hierarchical type perceptron 10p") based on the difference between the added-up outcome Oj(t) calculated by the function value error calculator 300 and the measured value Sj(t) as the teacher pattern, and based on the partial differential value calculated by the partial differential value calculating unit 10pr, a control unit 400 for selecting a correcting unit 12p and a partial differential function learning unit 60p from among the plurality of the correcting units 12p and partial differential function learning units 60p and controlling the correcting unit 12p and the partial differential function learning unit 60p thus selected to have the selected correcting unit 12p and the selected partial differential function learning unit

60p operate repeatedly for a predetermined number of times (until the difference becomes small enough), and a data collecting unit 500 for outputting the input data of the respective hierarchical type perceptrons 10p corresponding to unknown vector components as unknown quantity estimated outcomes under the condition that the input data of the hierarchical type perceptrons 10p has been corrected by the correcting units 12p for the predetermined number of times. It is herein assumed that each of the hierarchical type perceptrons 10p has sufficiently learned functions based on the Biot-Savart law with known input patterns and teacher patterns. Furthermore, the operations of the hierarchical type perceptrons 10p may be performed synchronously or asynchronously.

[0051]

Furthermore, each of the partial differential function learning units 60p is adapted to alternately repeat the two ways of learning: namely, the learning of the hierarchical type perceptron 10p based on the difference calculated by the function value error calculator 300 (for example, a learning of back propagation) and the learning of the hierarchical type perceptron 10p based on the difference calculated by the partial differential value error calculator 30pr, thereby making it possible for each of the hierarchical type perceptrons 10p to learn the partial differential function without losing the learning results so much.

[0052]

Each of the correcting units 12p is adapted to correct an unknown quantity based on the difference between the added-up outcome Oj(t) calculated by the function value error calculator 300 and the measured value Sj(t) as the teacher pattern, and based on the partial differential value calculated by the partial differential value calculating unit 10pr. The calculating unit 10pr, correcting unit 12p, and the function value error calculator 300 collectively constitute an unknown quantity estimating section. The operation of the unknown quantity estimating section will be described in detail hereinlater. The unknown quantity estimating section is operated to slightly change the input data of one of the hierarchical type perceptrons 10p corresponding to an unknown vector component after the hierarchical type perceptrons 10p have completed the learning based on the Biot-Savart law in order to obtain an output pattern and a corresponding partial differential value. Also, it is assumed that the unknown quantity estimating apparatus has calculated in advance a partial differential value in the case that the known input corresponding to the unknown vector component has been slightly changed in accordance with the numerical differentiation method or the like, and stored therein the partial differential value as a partial differential value teacher pattern. In the condition thus prepared, the control unit 400 is operated to select a partial differential function learning unit 60p from a plurality of partial differential function learning units 60p and control the selected partial differential function learning unit 60p to have the selected partial differential function learning unit 60p operate repeatedly for a predetermined number of times. In the way, a back propagation learning is carried out, and a load and a threshold value of a neuronal component constituting each of the hierarchical type perceptrons 10p is

determined so that a function based on the Biot-Savart law and an operation equivalent to the partial differential numerical arithmetic of the function can be realized.

[0053]

Furthermore, the load and the threshold value thus determined as a learning outcome for the selected hierarchical type perceptrons 10p can be adopted as a load and a threshold value for each of hierarchical type perceptrons other than the selected hierarchical type perceptrons 10p. This leads to the fact that the hierarchical type perceptrons other than the selected hierarchical type perceptrons 10p are not required to learn their partial differential functions, thereby drastically reducing the learning time. After the learning process is completed, in place of the partial differential function learning unit 60p, the control unit 400 is operated to select a correcting unit 12p from among a plurality of correcting units. The data collecting unit 500 is then operated to output the input data of the respective hierarchical type perceptrons 10p corresponding to unknown vector components as unknown quantity estimated outcomes when the input data of the hierarchical type perceptrons 10p has been corrected by the correcting units 12p for the predetermined number of times. As will be seen from the foregoing description, it is to be understood that the present embodiment of the organism magnetic field measuring apparatus can estimate the vector components as accurately as the embodiment shown in FIG. 6.

[0054]

[Fourth Embodiment]

Referring to the drawings, in particular to FIG. 9 of a block diagram, there is shown a fourth embodiment of the organism magnetic field measuring apparatus according to this present invention. The constitutional elements of the present embodiment of the organism magnetic field measuring apparatus as shown in FIG. 9 are the entirely the same as those of the previous embodiment of the organism magnetic field measuring apparatus according to this present invention as shown in FIGS. 7 and 8 except for the fact that the present embodiment of the organism magnetic field measuring apparatus comprises an input changing unit 15p for slightly changing an input, an output storing unit 16p for storing therein an output in response to the input not changed by input changing unit 15p and an output in response to the input changed by the input changing unit 15p, and a difference calculating unit 17p for calculating the difference between the output in response to the input not changed by input changing unit 15p and the output in response to the input changed by the input changing unit 15p, respectively stored in the output storing unit 16p, in place of the partial differential value calculating units 10pr provided in the respective hierarchical type perceptrons in the previous embodiment shown in FIGS. 7 and 8.

[0055]

Accordingly, the present embodiment of the organism magnetic field measuring apparatus can calculate the difference between the output in response to the regular input and the output in response to the slightly changed input. The difference between the output in response to the regular input and the output in response to the slightly changed input corresponds to a partial differential value. This leads to the

fact that the present embodiment of the organism magnetic field measuring apparatus can achieve the same advantage of the previous embodiment shown in FIGS. 7 and 8 while eliminating the need of learning the partial differential function, thereby largely reducing the leaning time.

[0056]

[Fifth Embodiment]

Referring to the drawings, in particular to FIG. 10 of a block diagram, there is shown a unit of a fifth embodiment of the organism magnetic field measuring apparatus according to this present invention. The organism magnetic field measuring apparatus is shown in FIG. 10 as comprising: a plurality of Biot-Savart arithmetical calculating units 11i each for performing an arithmetical calculation in accordance with the Biot-Savart law, a current element collecting unit 40a for collecting vector components of current elements estimated by the Biot-Savart arithmetical calculating units 11i and for outputting the collected vector components as an analysis outcome, a plurality of correction quantity calculating units 41i each for calculating correction quantities Δx, Δy, and Δz on the basis of the three-dimensional coordinate values provided by the method shown in FIG. 1 and/or by the apparatus shown in FIG. 5, a plurality of vertex extracting units 42i each for extracting coordinate of each of the adjacent vertexes, for which the estimated vector component of the current element is to be distributed, the basis of the code of the calculated correction quantities Δx, Δy, and Δz, a plurality of standardizing unit 43i each for standardizing a correction vector calculated based on the correction quantities Δx, Δy, and Δz, a plurality of redistributing ratio calculating unit 44i each for calculating a redistributing ratio based on the absolute value of each component of the standardized correction vectors, a plurality of redistributing units 45i each for redistributing an estimated value to the vector component of the current element estimated for each of the extracted vertexes on the basis of the estimated vector component of the current element estimated and the calculated redistributing ratio, a plurality of estimated value updating units 46i each for updating the estimated vector component of the current element in response to the redistributed estimated value, and a repeat control unit 47 for controlling the Biot-Savart arithmetical calculating unit 11i, the correction quantity calculating unit 41i, the vertex extracting unit 42i, the standardizing unit 43i, the redistributing ratio calculating unit 44i, the redistributing unit 45i and the estimated value updating unit 46i to have the Biot-Savart arithmetical calculating unit 11i, the correction quantity calculating unit 41i, the vertex extracting unit 42i, the standardizing unit 43i, the redistributing ratio calculating unit 44i, the redistributing unit 45i and the estimated value updating unit 46i repeatedly operate until the correction quantities Δx, Δy, and Δz becomes vanishingly small.

[0057]

The estimated value updating unit 46i is operative to update the estimated vector component of the current not by simply adding the redistribution ratio to the estimated vector component of the current element, but by adding the average of all of the redistribution ratios to the estimated vector component of the current element. The correction quantity calculating unit 41i is operative to calculate the correction quantities Δx, Δy, Δz by computing the partial differential value of the function value calculated by for example Biot-Savart arithmetical calculation units.

[0058]

The operation of the organism magnetic field measuring apparatus thus constructed will be described hereinlater. Each of the Biot-Savart arithmetical calculation units 11i is operated to carry out the computation in accordance with the following equation:

$$gij = (i\ 0/4\ \delta)\ \{(Yji \times pxi - Xji \times pyi)\ /Rji^3\}$$

where i 0 is intended to mean a magnetic permeability, i (i =1,2, ... , N) is intended to mean the current element contained in each vertex of the respective small stereoscopic segments, j (j=1,2, ... ,m) is intended to mean measuring points. When it is assumed that the measuring condition of each of the measuring points is represented by Pj = (xj, yj, zj) and the unknown physical quantity of each of the current elements is represented by Ui = (xi, yi, zi, pxi, pyi), the following equation is derived.

Xji = xj − xi, Yji = yj − yi, Zji = zj − zi, and $Rji = (Xji^2 + Yji^2 + zji^2)^{1/2}$.

[0059]

Thus, the partial differential values of the above-mentioned equations partially differentiated with the respective unknown quantities can be obtained by supplying the correction quantity calculating units 41 with the outcome respectively outputted from the Biot-Savart arithmetical calculating units 11i. The partial differential values can be computed in accordance with the following Equations 5 through 9.

[0060]

[Equation 5]

$$\frac{\partial g\,i\,j}{\partial x\,i} = \frac{\mu 0}{4\pi}\left\{\frac{3Xj\,i\ (Yj\,i\,Px\,i - Xj\,i\,py\,i) + Rj\,i^2\,py\,i)}{Rj\,i^5}\right\}$$

[0061]

[Equation 6]

$$\frac{\partial g\,i\,j}{\partial y\,i} = \frac{\mu 0}{4\pi}\left\{\frac{3Yj\,i\ (Yj\,i\,Py\,i - Xj\,i\,px\,i) - Rj\,i^2\,px\,i)}{Rj\,i^5}\right\}$$

[0062]

[Equation 7]

$$\frac{\partial g\,i\,j}{\partial z\,i} = \frac{\mu 0}{4\pi}\left\{\frac{3Zj\,i\ (Yj\,i\,Px\,i - Xj\,i\,py\,i)}{Rj\,i^5}\right\}$$

[0063]

[Equation 8]

$$\frac{\partial g_{ij}}{\partial P_{xi}} = \frac{\mu 0}{4\pi} \frac{Y_{ji}}{R_{ji}^3}$$

[0064]

[Equation 9]

$$\frac{\partial g_{ij}}{\partial P_{yi}} = -\frac{\mu 0}{4\pi} \frac{X_{ji}}{R_{ji}^3}$$

[0065]

The correction quantities Δx, Δy, Δz can be obtained based on the partial differentiation computation carried out in accordance with the Equations 5 through 7 and Sj−Oj. With the correction quantities Δx, Δy, Δz thus obtained, the adjacent vertexes, for which the estimated vector components of the current elements are to be distributed, can be extracted by the vertex extracting unit 42i based on the codes of the correction quantities Δx, Δy, Δz. As best shown in FIG. 11, concretely, vertexes respectively shown by double circles are extracted as adjacent vertexes, for which the estimated vector components of the current elements are to be distributed, by the fact that the correction vectors respectively shown by dotted lines are obtained. The correction vectors are then standardized by the standardizing unit 43i, the redistributing ratio is calculated by the redistributing ratio calculating unit 44i based on the absolute value of each component of the standardized correction vectors, and an estimate is redistributed by the redistributing unit 45i to the vector component of the current element estimated for each of the extracted vertexes extracted by the extracting unit 42i. In this case, each of the vector components of the current elements may be drastically redistributed on the basis of a plurality of correction vectors. Simply adding the vector components of the current elements may result in the fact that the value before the redistribution is by far different from the value after the redistribution, thereby undermining the reliability of the stability of the estimation. In order to solve this problem, the estimated value updating unit 46i is operative to update the estimated vector component of the current by adding to the estimated vector component of the current element the average of all of the redistribution ratios calculated based on a plurality of standardized correction vectors.

[0066]

The repeat control unit 47 is operated to control the Biot-Savart arithmetical calculating unit 11i, the correction quantity calculating unit 41i, the vertex extracting unit 42i, the standardizing unit 43i, the redistributing ratio calculating unit 44i, the redistributing unit 45i and the estimated value updating unit 46i to have the Biot-Savart arithmetical calculating unit 11i, the correction quantity calculating unit 41i, the vertex extracting unit 42i, the standardizing unit 43i, the redistributing ratio calculating unit 44i, the redistributing unit 45i and the estimated value updating unit 46i repeatedly operate until the correction quantities Δx, Δy, and Δz becomes vanishingly small for

all of the vertexes, thereby highly improve the accuracy of the estimates of the current elements. While the estimation process is performed by the repeat control unit 47, Equation 5, Equation 6, and Equation 7 are not directly influenced by the correction quantities Δx, Δy, Δz by the reason that the three-dimensional coordinate values of each vertex of the respective small stereoscopic segments are to be fixed. The aforementioned equations are, on the other hand, indirectly influenced by the correction quantities Δx, Δy, Δz by the fact that the vector components of the current elements are changed through the redistribution process. This means that through out the processes carried out in accordance with Equation 5, Equation 6, Equation 7, Equation 8, and Equation 9, Xji, Yji, Zji, and Rji, remain unchanged while, on the other hand, only pxi and pyi are changed, thereby ensuring that the highly estimated pxi and pyi are obtained. The conventional organism magnetic field measuring apparatus tends to remain currents canceling each other at positions at which in fact no current flows even if the currents canceling each other are placed in the vicinity of each other as shown, for example, in FIG. 12(A). The present embodiment of the organism magnetic field measuring apparatus, on the other hand, carries out the redistribution process, thereby making it possible for the currents canceling each other to be displayed at positions at which actually the currents flow as shown in FIG. 12(B). In FIGS. 12(A) and 12(B), a black dot is intended to mean a vertex to be processed and a circle is intended to mean a vertex placed in the vicinity of the vertex.

[0067]

Examples of the magnetic field source estimating outcomes obtained approximately at the time the Q wave occurs based on magnetic field distribution maps are shown in FIGS. 14 to 18. The magnetic field distribution maps have been prepared by synchronously adding a plurality of magnetocardiograms measured at 3 cm intervals with 6 x 6 points to an electrocardiography using a one-channel magneto meter. As will be seen from FIGS. 14 to 18, it is to be understood that the magnetic field source estimating outcomes precisely represent a cardiac volume current, which is medically confirmed, with a high degree of accuracy. FIG. 13 show information on vertexes with depth of 6 cm obtained based on MRI pictorial images. FIGS. 14 to 18 show estimating outcomes respectively obtained at the time 35 msec, 33 msec, 30 msec, 25 msec, and 20 msec prior to the occurrence of R wave. The large black dots collectively represent a cardiac wall, and line segments respectively originating from the black dots represent current elements.

[0068]

In the present embodiment of the organism magnetic field measuring apparatus according to the present invention, the hierarchical type perceptrons may be adopted in place of the Biot-Savart arithmetical calculating units.

[0069]

[Seventh Embodiment]

Referring to the drawings, in particular to FIG. 19 of a flowchart, there is

shown a seventh preferred embodiment of the organism magnetic field measured outcome display method according to this present invention. As shown in FIG. 19, the organism magnetic field measured outcome display method comprises the steps of: waiting for receiving the position and the magnitude (the absolute value of an excitation current) of the current element in a plane corresponding to the tomogram image at a predetermined point of time (step SP 1), assigning a circle having a diameter corresponding to the magnitude of each of a plurality of the current elements to each of the current elements (step SP 2), displaying the organism tomogram image (step SP 3), displaying the circle assigned to each of the current elements along with the organism tomogram image for each of vivo points (step SP 4), judging whether or not the end of the excitation current display is instructed (step SP 5), and waiting for receiving the position and the magnitude of the current element in a plane corresponding to the tomogram image at another point of time when it is judged in the step SP5 that the end of the excitation current display is not instructed (step SP 6). Then, the step SP6 goes back to the step SP2. When it is, on the other hand, judged in the step SP5 that the end of the excitation current display is not instructed, the process goes to END. In the step SP2, the diameter of the circle assigned to each of the current elements may precisely correspond to the magnitude of each of the current elements. Alternatively, the magnitude of each of the current elements may be divided into a plurality of magnitude grades, and the diameter of the circle assigned to each of the current elements may correspond to the magnitude grade of each of the current elements.

[0070]

[Eighth Embodiment]

Referring to the drawings, in particular to FIG. 20 of a flowchart, there is shown an eighth preferred embodiment of the organism magnetic field measured outcome display method according to this present invention. The organism magnetic field measured outcome display method comprises the steps of: waiting until a point at which an internal organ is placed is detected on a plane corresponding to the tomogram image (step SP 1), assigning a circle having a predetermined diameter to the detected point at which the internal organ is placed (step SP 2), waiting until the position and the magnitude of each of the current elements is obtained at a predetermined point of time on the above-mentioned plane (step SP 3), replacing the circle assigned to the point in the step SP2 with a high-lightened circle having a diameter corresponding to the magnitude of each of the current elements (step SP 4), displaying the organism tomogram image (step SP 5), displaying the circle assigned to the detected point along with the organism tomogram image at the detected point (step SP 6), judging whether or not the end of the excitation current display is instructed (step SP 7), and waiting for the position and the magnitude of the current element in a plane corresponding to the tomogram image at another point of time when it is judged in the step SP7 that the end of the excitation current display is not instructed (step SP 8). Then, the step SP8 goes back to the step SP4. When it is, on the other hand, judged in the step SP7 that the end of the excitation current display is not instructed, the process goes to END.

[0071]

Examples of the excitation currents displayed by the present embodiment of the organism magnetic field measured outcome display method are shown in FIG. 21. As will be seen from FIG. 21, the excitation currents are remarkably visible. The circles are displaced at the point at which the internal organ is placed. In addition, a clearance between the circles is enlarged, thereby making it possible for an operator to recognize the tomogram image as a background. In particular, the present embodiment of the organism magnetic field measured outcome display method can display the excitation currents on the time series, thereby making it possible for an operator to easily recognize, for example, the condition of the maximal excitation current in the process of changing.

[0072]

[Ninth Embodiment]

Referring to the drawings, in particular to FIG. 22 of a flowchart, there is shown a ninth preferred embodiment of the organism magnetic field measured outcome display method according to this present invention. The organism magnetic field measured outcome display method comprises the steps of: waiting for receiving the position and the magnitude of the current element at a predetermined point of time (step SP 1), assigning a sphere having a diameter corresponding to the magnitude of each of a plurality of the current elements to each of the current elements (step SP 2), three-dimensionally displaying a semi-transparent organism structure reference image (step SP 3), displaying the sphere assigned to each of the current elements along with the semi-transparent organism structure reference image for each of corresponding points (step SP 4), judging whether or not the end of the excitation current display is instructed (step SP 5), and waiting for receiving the position and the magnitude of the current element at another point of time when it is judged in the step SP5 that the end of the excitation current display is not instructed (step SP 6). Then, the step SP6 goes back to the step SP2. When it is, on the other hand, judged in the step SP5 that the end of the excitation current display is not instructed, the process goes to END.

[0073]

As will be seen from the foregoing description, it is to be understood that the present embodiment of the organism magnetic field measured outcome display method according to the present invention can display the sphere having a diameter corresponding to the magnitude of each of a plurality of the current elements along with the semi-transparent organism structure reference image for each of corresponding points on the time series, thereby making it possible for an operator to easily recognize the three-dimensional propagation direction of the excitation current.

[0074]

[Tenth Embodiment]

Referring to the drawings, in particular to FIG. 23 of a block diagram, there is shown a tenth preferred embodiment of the organism magnetic field measured outcome displaying apparatus according to this present invention. The organism magnetic field measured outcome displaying apparatus is shown in FIG. 23 as comprising: an

analyzed outcome storing unit 600 for storing therein current elements analyzed outcomes, a circle assigning unit 700 for assigning a circle having a diameter corresponding to the magnitude of each of current elements to each of the current elements, a tomogram image displaying unit 800 for displaying an organism tomogram image, a circle displaying unit 900 for displaying the assigned circle having a diameter corresponding to the magnitude of each of a plurality of the current elements along with the organism tomogram image.

[0075]

As will be seen from the foregoing description, it is to be understood that the present embodiment of the organism magnetic field measured outcome displaying apparatus thus constructed can display the circle having a diameter corresponding to the magnitude of each of a plurality of the current elements along with the organism tomogram image, thereby remarkably increase the visibility of the excitation currents. Furthermore, the present embodiment of the present embodiment of the organism magnetic field measured outcome displaying apparatus can display the circle along with the organism tomogram image on the time series, thereby making it possible for an operator to easily recognize the three-dimensional propagation direction of the excitation current. In the previous seventh to tenth embodiment according to the present invention, the circle may be replaced with a square, a cube, or the like as long as degrease in visibility is admitted to some extend. It will be understood by those skilled in the art that the foregoing description is in terms of preferred embodiment of the present invention wherein various changes and modification may be made without departing from the spirit and scope of the invention, as set forth in the appended claims.

[0076]

[Effects of the Invention]

As will be seen from the foregoing description, it is to be understood, the tomogram image processing method as set forth in claim 1 comprising the steps of: a) carrying out an interpolation operation on a plurality of tomogram images of a test boy sliced in an area at predetermined intervals to obtain stereoscopic image data elements; b) dividing said area into small stereoscopic segments; c) counting the number of said stereoscopic image data elements for each of said small stereoscopic segments; and d) binarizing said small stereoscopic segments on the basis of the number of said stereoscopic image data elements, has an effect of obtaining the stereoscopic image data elements corresponding to all of the small stereoscopic segments by carrying out the interpolation operation on a plurality of tomogram images of the test body even through some tomogram images sliced at the intervals should fail to be provided. Further, the tomogram image processing method thus constructed can obtain a simplified stereoscopic image by the reason that the small stereoscopic segments are binarized on the basis of the number of the stereoscopic image data elements. This leads to the fact that the stereoscopic image obtained and displayed by the tomogram image processing method as set forth in claim 1 makes it possible for an operator to easily distinguish an area and/or a stereoscopic segment where an internal organ or the

like is placed.
[0077]

A tomogram image processing apparatus as set forth in claim 2, comprising: interpolation carrying out means (3) for carrying out an interpolation operation on a plurality of tomogram images of a test boy sliced in an area at predetermined intervals to obtain stereoscopic image data elements; area dividing means (7) for dividing said area into small stereoscopic segments; stereoscopic image counting means (8) for counting the number of said stereoscopic image data elements for each of said small stereoscopic segments; and binarizing means (9, 10) for binarizing said small stereoscopic segments on the basis of the number of said stereoscopic image data elements has an effect of obtaining the stereoscopic image data elements corresponding to all of the small stereoscopic segments by carrying out the interpolation operation on a plurality of tomogram images of the test body even through some tomogram images sliced at the intervals should fail to be provided. Further, the tomogram image processing apparatus thus constructed can obtain a simplified stereoscopic image by the reason that the small stereoscopic segments are binarized on the basis of the number of the stereoscopic image data elements. This leads to the fact that the stereoscopic image obtained and displayed by the tomogram image processing apparatus as set forth in claim 2 makes it possible for an operator to easily distinguish an area and/or a stereoscopic segment where an internal organ or the like is placed.
[0078]

The organism magnetic field measuring method as set forth in claim 3, has an effect of obtaining the data on the magnetic field source for each of a plurality of vertexes of said small stereoscopic segments by the reason that data on said magnetic field sources included in the results of the Biot-Savart law calculations is corrected until the difference between said calculated magnetic field value and a measured magnetic field value becomes vanishingly small. Furthermore, the number of unknown factors to be estimated can be largely reduced in comparison with the conventional method by the reason that the position of each of the vertexes of the small stereoscopic segments is known. The organism magnetic field measuring method thus constructed degreases the number of measuring points, thereby as a whole reducing the operation load. The organism magnetic field measuring method as set forth in claim 4 has an effect of obtaining accurate information on the magnetic field source by the reason that even magnetic field source vectors assigned in positions adjoining to each other, equal to each other in magnitude but opposing to each other in direction can be calibrated. Furthermore, the organism magnetic field measuring method thus constructed degreases the number of measuring points by the reason that one vertex of one small stereoscopic segment serves as the vertex of the adjacent small stereoscopic segment, thereby as a whole reducing the operation load.
[0079]

The organism magnetic field measuring apparatus as set forth in claim 5, has an effect of obtaining the data on the magnetic field source for each of a plurality of vertexes of said small stereoscopic segments by the reason that data on said magnetic

field sources included in the results of the Biot-Savart law calculations is corrected until the difference between said calculated magnetic field value and a measured magnetic field value becomes vanishingly small. Furthermore, the number of unknown factors to be estimated can be largely reduced in comparison with the conventional apparatus by the reason that the position of each of the vertexes of the small stereoscopic segments is known. The organism magnetic field measuring apparatus thus constructed degreases the number of measuring points, thereby as a whole reducing the operation load. The organism magnetic field measuring apparatus as set forth in claim 6 has an effect of obtaining accurate information on the magnetic field source by the reason that even magnetic field source vectors assigned in positions adjoining to each other, equal to each other in magnitude but opposing to each other in direction can be calibrated. Furthermore, the organism magnetic field measuring apparatus thus constructed degreases the number of measuring points by the reason that one vertex of one small stereoscopic segment serves as the vertex of the adjacent small stereoscopic segment, thereby as a whole reducing the operation load.

[0080]

The organism magnetic field-measured outcome display method as set forth in claim 7 of displaying an organism magnetic field-measured outcome along with an organism structure reference image, has an effect of making it possible for an operator to recognize, for example, the distributed condition of the maximal organism magnetic field-measured outcome in comparison with the case that the magnetic field measured outcome is displayed with the direction and the length of the arrows. Moreover, the organism magnetic field-measured outcome display method thus constructed can dynamically display the organism magnetic field measured outcome, thereby making it possible for an operator to easily recognize, for example, the time-variant fluctuation of the distributed condition of the maximal organism magnetic field measured outcome. The organism magnetic field-measured outcome display method as set forth in claim 8, in which the reference graphic is in the form of a circular shape, has an effect of considerably enlarging a clearance between the reference graphics, thereby making it possible for an operator to recognize the organism structure reference image as a background.

[0081]

The organism magnetic field-measured outcome display apparatus as set forth in claim 9 for displaying an organism magnetic field-measured outcome along with an organism structure reference image, has an effect of making it possible for an operator to recognize, for example, the distributed condition of the maximal organism magnetic field-measured outcome in comparison with the case that the magnetic field measured outcome is displayed with the direction and the length of the arrows. Moreover, the organism magnetic field-measured outcome display apparatus thus constructed can dynamically display the organism magnetic field measured outcome, thereby making it possible for an operator to easily recognize, for example, the time-variant fluctuation of the distributed condition of the maximal organism magnetic field measured outcome.

[0082]

The organism magnetic field-measured outcome display apparatus as set forth in claim 10, in which the reference graphic is in the form of a circular shape, has an effect of considerably enlarging a clearance between the reference graphics, thereby making it possible for an operator to recognize the organism structure reference image as a background.

[Brief Description of the Drawings]

The objects, features, and advantages of an imaging device correcting apparatus according to the present invention will become apparent as the description proceeds when taken in conjunction with the accompanying drawings.

[0083]

FIG. 1 is a flowchart showing a preferred embodiment of the tomogram image processing method according the present invention.

[0084]

FIG. 2 is a schematic diagram showing an example of a tomogram image.

[0085]

FIG. 3 is a plan view diagrammatically explaining a relationship between small stereoscopic segments belonging to a small stereoscopic segment group to be displayed and a small stereoscopic segment group to be displayed.

[0086]

[FIG. 4]

It is a perspective view corresponding to FIG. 3.

[0087]

FIG. 5 is a block diagram showing a preferred embodiment of the tomogram image processing apparatus according to the present invention.

[0088]

FIG. 6 is a block diagram showing a preferred embodiment of the organism magnetic field measuring apparatus according to the present invention.

[0089]

FIG. 7 is a block diagram showing another preferred embodiment the organism magnetic field measuring apparatus according to the present invention.

[0090]

FIG. 8 is a schematic diagram showing the detailed construction of the part corresponding to one hierarchical type perceptron.

[0091]

FIG. 9 is a block diagram showing another preferred embodiment the organism magnetic field measuring method according to the present invention.

[0092]

FIG. 10 is a block diagram showing yet another embodiment of the magnetic field source measuring apparatus according to the present invention.

[0093]

FIG. 11 is a schematic diagram explaining a process for extracting an adjacent vertex, for which an estimated vector component of a current element is to be

distributed.

[0094]

FIG. 12 is a schematic diagram explaining a process for estimating a current element carried out during a redistribution operation.

[0095]

FIG. 13 is an illustration representing information on vertexes with depth of 6 cm obtained based on MRI pictorial images.

[0096]

FIG. 14 is an illustration showing an estimating outcome obtained at the time 35 msec prior to the occurrence of R wave.

[0097]

FIG. 15 is an illustration showing an estimating outcome obtained at the time 33 msec prior to the occurrence of R wave.

[0098]

FIG. 16 is an illustration showing an estimating outcome obtained at the time 30 msec prior to the occurrence of R wave.

[0099]

FIG. 17 is an illustration showing an estimating outcome obtained at the time 25 msec prior to the occurrence of R wave.

[0100]

FIG. 18 is an illustration showing an estimating outcome obtained at the time 20 msec prior to the occurrence of R wave.

[0101]

FIG. 19 is a flowchart showing a preferred embodiment of the organism magnetic field-measured outcome display method according to the present invention.

[0102]

FIG. 20 is a flowchart showing another preferred embodiment of the organism magnetic field-measured outcome display method according to the present invention.

[0103]

FIG. 21 is an illustration showing examples of excitation currents displayed by the embodiment shown in FIG. 20.

[0104]

FIG. 22 is a flowchart showing another preferred embodiment of the organism magnetic field-measured outcome display method according to the present invention.

[0105]

FIG. 23 is a block diagram showing an excitation current displaying apparatus as a preferred embodiment of the organism magnetic field-measured outcome displaying unit according to the present invention.

[0106]

[Description of Notations]

3	Tomogram image interpolating unit
7	stereoscopic segment assigning unit
8	pixel number counting unit

9 judging unit
10 display-stereoscopic segment assigning unit
20, 200 adding unit
30, 300 error calculator
41i correction quantity calculating unit
42i vertex extracting unit
43i standardizing unit
44i redistributing ratio calculating unit
45i redistributing unit
46i estimated value updating unit
40, 500 data collecting unit
101,102, ... ,10m hierarchical type perceptrons
111,112, ... ,11m Biot-Savart arithmetical calculating unit
111a,112a, ... ,11ma, 121,122, ... ,12m correcting unit
700 circle assigning unit
800 tomogram image displaying unit
900 circle displaying unit

ABSTRACT OF THE DISCLOSURE

PURPOSE:
To obtain a solid model from tomogram images
CONSTITUTION:
The construction of the foregoing methods according to the present invention comprising the steps of: performing interpolation arithmetical calculation on tomogram images taken at respective predetermined intervals of an object such as, for example, internal organs to obtain stereoscopic image data elements, generating small stereoscopic segments in correspondence with the tomogram images and/or interpolation tomogram images to count pixel numbers contained in each of the small stereoscopic segments, assigning the small stereoscopic segments to a display-stereoscopic segment only when the counted value of the pixel numbers is larger in number than a predetermined threshold, and visually displaying only the small stereoscopic segment assigned to the display-stereoscopic segment.

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 06-028455
(43)Date of publication of application : 04.02.1994

(51)Int.Cl. G06F 15/62
A61B 5/055
// G09G 5/36

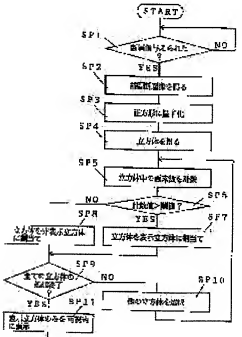
(21)Application number : 04-235534
(22)Date of filing : 03.09.1992

(71)Applicant : DAIKIN IND LTD
(72)Inventor : UEDA TOMOAKI

(30)Priority
Priority number : 04122295 Priority date : 14.05.1992 Priority country : JP

(54) TOMOGRAPHIC IMAGE PROCESSING METHOD, LIVING BODY MAGNETIC FIELD MEASURING METHOD, LIVING BODY MAGNETIC FIELD MEASURING RESULT DISPLAY METHOD AND DEVICES THEREFOR

(57)Abstract:
PURPOSE: To obtain delicate image data, based on a tomographic image at every prescribed interval by dividing a space which becomes a processing object into prescribed small stereo scopic areas, counting stereoscopic image data contained in each small stereoscopic area, and binarizing the small stereoscopic area based on a counting value.
CONSTITUTION: Based on a tomographic image at a prescribed interval, an interpolating operation is executed and stereoscopic image data is obtained (SP4). A space which becomes a processing object is divided into prescribed small stereoscopic areas, stereoscopic image data contained in each stereoscopic area is counted (SP5), and based on a counting value, the small stereoscopic area is binarized. Even if only the tomographic image at every prescribed interval is obtained, the stereoscopic image data is obtained so as to correspond to all spaces by executing an interpolating operation, and also, by binarizing the small stereoscopic area based on the number of stereoscopic image data contained in the divided small stereoscopic areas, a simplified stereoscopic image can be obtained. Accordingly, in the case where the displayed is executed visibly, the part corresponding to internal organs, etc., and the part corresponding to the space can be recognized simply.



LEGAL STATUS

[Date of request for examination] 31.07.1996
[Date of sending the examiner's decision of rejection] 19.10.1999
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]	
[Patent number]	3084951
[Date of registration]	07.07.2000
[Number of appeal against examiner's decision of rejection]	11-18535
[Date of requesting appeal against examiner's decision of rejection]	18.11.1999
[Date of extinction of right]	

(19)日本国特許庁（ＪＰ）　(12)**公開特許公報（Ａ）**　(11)特許出願公開番号

特開平6－28455

(43)公開日　平成6年(1994)2月4日

(51)Int.Cl.[5]	識別記号	庁内整理番号	ＦＩ	技術表示箇所
Ｇ０６Ｆ　15/62	３９０　Ｂ	9287－5L		
Ａ６１Ｂ　5/055				
// Ｇ０９Ｇ　5/36		9177－5G		
		8932－4C	Ａ６１Ｂ　5/ 05　３８０	

審査請求　未請求　請求項の数10(全 23 頁)

(21)出願番号　特願平4－235534

(22)出願日　平成4年(1992)9月3日

(31)優先権主張番号　特願平4－122295

(32)優先日　平4(1992)5月14日

(33)優先権主張国　日本（ＪＰ）

(71)出願人　000002853
ダイキン工業株式会社
大阪府大阪市北区中崎西２丁目４番12号
梅田センタービル

(72)発明者　上田　智章
滋賀県草津市岡本町字大谷1000番地の２
ダイキン工業株式会社滋賀製作所内

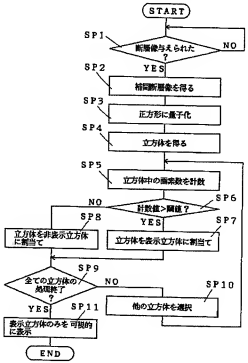
(74)代理人　弁理士　津川　友士

(54)【発明の名称】　断層像処理方法、生体磁場測定方法、生体磁場測定結果表示方法およびこれらの装置

(57)【要約】

【目的】　断層像に基づいてソリッドモデルを得る。

【構成】　所定間隔毎の断層像に基づいて補間演算を行なって補間断層像を得、断層像または補間断層像に対応させて小立方体を生成し、各小立方体に含まれる画素数を計数して、計数値が閾値よりも大きい場合にのみ小立方体を表示立方体に割り当て、表示立方体に割当てられた小立方体のみを可視的に表示する。



1

【特許請求の範囲】

【請求項1】　所定間隔毎の断層像に基づいて補間演算を行なって立体像データを得、処理対象となる空間を所定の小立体領域に区分して各小立体領域に含まれる立体像データを計数し、計数値に基づいて小立体領域を2値化することを特徴とする断層像処理方法。

【請求項2】　所定間隔毎の断層像に基づいて補間演算を行なって立体像データを得る断層像補間手段（3）と、処理対象となる空間を所定の小立体領域に区分する空間区分手段（7）と、区分された各小立体領域に含まれる立体像データを計数する立体像データ計数手段（8）と、計数値に基づいて小立体領域を2値化する2値化手段（9）（10）とを含むことを特徴とする断層像処理装置。

【請求項3】　請求項1の断層像処理方法により得られた小立体領域の頂点の位置情報に基づいて異なる磁場源情報に基づく複数のビオ・サバールの法則の演算を行ない、各演算結果を累積加算して得られる磁場演算値と測定した磁場計測値との差を算出し、算出した差に基づいて各演算式に含まれる磁場源情報を補正し、差が十分に小さくなるまで上記一連の処理を反復してから各演算式に含まれる磁場源情報を生体磁場測定結果として出力することを特徴とする生体磁場測定方法。

【請求項4】　算出した差に基づく補正に代えて、各小立体領域の各頂点の各座標成分の修正量を算出し、各座標成分の修正量の符号に基づいて修正対象頂点を得るとともに、各座標成分の修正量に基づいて、得られた修正対象頂点に対して磁場源情報推定値の再配分を行なう処理を採用する請求項3に記載の生体磁場測定方法。

【請求項5】　請求項1の断層像処理方法により得られた小立体領域の頂点の位置情報に基づいて異なる磁場源情報に基づく複数のビオ・サバールの法則の演算を行なう演算手段（111）（112）・・・（11m）（101）（102）・・・（10m）と、各演算手段（111）（112）・・・（11m）（101）（102）・・・（10m）から出力される演算結果を累積加算する累積加算手段（20）（200）と、累積加算手段（20）（200）から出力される累積加算結果と磁場計測値とを入力として誤差を算出する誤差算出手段（30）（300）と、算出誤差に基づいて各演算手段（111）（112）・・・（11m）（101）（102）・・・（10m）における磁場源情報の補正を行なう補正手段（111a）（112a）・・・（11ma）（121）（122）・・・（12m）と、補正手段（111a）（112a）・・・（11ma）（121）（122）・・・（12m）による補正が施された結果を収集して生体磁場測定結果として出力する補正結果収集手段（40）（500）とを含むことを特徴とする生体磁場測定装置。

【請求項6】　補正手段として、各小立体領域の各頂点の各座標成分の修正量を算出する修正量算出手段（41）と、各座標成分の修正量の符号に基づいて修正対象頂点を抽出する修正対象頂点抽出手段（42i）と、各座標成分の修正量に基づいて、得られた修正対象頂点に対して磁場源情報推定値の再配分を行なう再配分手段（43i）（44i）（45i）（46i）とを含むものを用いる請求項5に記載の生体磁場測定装置。

2

【請求項7】　生体磁場測定結果を生体構造参照像と共に表示する方法であって、生体内の複数の点のそれぞれに対応する生体磁場測定値の絶対値に基づいて単位図形のサイズを設定し、生体構造参照像を表示するとともに、生体構造参照像の該当位置に設定されたサイズの単位図形を表示することを特徴とする生体磁場測定結果表示方法。

【請求項8】　単位図形が円である請求項7に記載の生体磁場測定結果表示方法。

【請求項9】　生体磁場測定結果を生体構造参照像と共に表示する装置であって、生体内の複数の点のそれぞれに対応する生体磁場測定値の絶対値に基づいて単位図形のサイズを設定する単位図形サイズ設定手段（700）と、生体構造参照像を表示する生体像表示手段（800）と、生体構造参照像の該当位置に設定されたサイズの単位図形を表示する単位図形表示手段（900）とを含むことを特徴とする生体磁場測定結果表示装置。

【請求項10】　単位図形が円である請求項9に記載の生体磁場測定結果表示装置。

【発明の詳細な説明】

【0001】

【産業上の利用分野】この発明は断層像処理方法、生体磁場測定方法、生体磁場測定結果表示方法およびこれらの装置に関し、さらに詳細にいえば、所定間隔毎の断層像に基づいてきめ細かい像データを得るための新規な断層像処理方法およびその装置、断層像処理方法により得られたきめ細かい像データに基づいて生体磁場源の解析を行なうための新規な生体磁場測定方法およびその装置、ならびに生体磁場源の解析結果を把握し易い状態で表示するための新規な生体磁場測定結果表示方法およびその装置に関する。

【0002】

【従来の技術】従来から生体磁場解析結果を把握し易い状態で表示するために、ＭＲＩ画像等の断層像を可視的に表示した状態で磁場源を可視的に重畳して表示する方法が採用されている。また、磁場源を可視的に重畳表示する方法として、磁場源に最も近い断層像と重畳した状態で磁場源を2次元的に表示する方法および複数の断層像を3次元的に表示し、磁場源をも3次元的に表示する方法が提案されている。

【0003】また、生体磁場測定を測定する方法として、磁場源がシングル・ダイポールであると仮定した場合に対処するための測定方法および磁場源が複数電流素

片であると仮定した場合に対処するための測定方法が提案されている。前者の方法は、体表近傍における複数点の磁場測定結果に基づいてシングル・ダイポールの位置および方向性等を算出する方法である。また、後者の方法は、複数の電流素片（通常は３０～１００程度の電流素片）の存在を仮定しておき、電流素片の数よりも著しく多い測定点における磁場測定結果に基づいて演算を行ない、上記複数の電流素片の位置および方向性を算出する方法である。

【０００４】また、生体磁気計測結果に基づく磁場源解析を行なうことにより得られた電流素片を電流ベクトルとして表示するアローマップ表示、または、等磁線に基づくコンターマップ表示が知られている。そして、医療解析に用いる場合には、ＭＲＩ画像上に電流ベクトルを示す矢印、または等磁線をオーバーラップさせて表示することにより、臓器中における電流素片または等磁線を可視的に表示することが提案されている。

【０００５】

【発明が解決しようとする課題】上記磁場源表示方法のうち、２次元的に表示する方法を採用した場合には、磁場源が何れかの断層像上に位置する可能性が著しく低いとともに、選択された断層像に対する磁場源の相対位置（特に奥行き方向の相対位置）が全く把握できないのであるから、医師等が２次元的な重畳表示を見ても磁場源の位置を正確に把握することが非常に困難になってしまうという不都合がある。また、断層像では生体内部の臓器の有無を示しているのであるが、臓器の奥行き方向の形状が断層像の形状からずれてしまう可能性が高いのであるから、実際には断層像上において臓器が存在しない位置に磁場源が表示されてしまう可能性が高くなり、この点からも磁場源の位置を正確に把握することが非常に困難になってしまう。

【０００６】また、３次元的に表示する方法を採用した場合には、基準になる画像として複数の断層像が存在するだけであるから、臓器との位置関係が非常に把握しにくいのみならず、断層像以外に目印がないのであるから、磁場源の深さ、奥行きが非常に把握しにくいという不都合がある。上記生体磁場測定を測定する方法のうち、磁場源がシングル・ダイポールであると仮定した場合に対処するための測定方法を採用した場合には、測定結果としてシングル・ダイポールが得られるだけであるから、臓器の運動時に流れる体積電流に代表される分布性磁場源の測定には対処できないという不都合があるのみならず、深すぎる解に収束してしまい勝ちであるという不都合もある。

【０００７】また、磁場源が複数電流素片であると仮定した場合に対処するための方法を採用した場合には、分布性磁場源の測定が可能になるのである。しかし、一般的に、３０～１００程度の電流素片を想定することが必要になるのであるから、全ての電流素片の測定を行なおうとすれば、２００～１０００チャネル程度のアレイセンサを設けて多数の磁場計測値を得、得られた多数の磁場計測値に基づいて各電流素片の推定処理のための演算を行なう必要がある。そして、上述の場合に対する推定処理のための演算負荷はテラ・フロップスが要求されるのであるから、システム全体として著しく大規模になるとともに、高価になってしまうという不都合がある。また、推定処理においてローカルミニマに収束してしまう確率が高く、正確な電流素片の推定を達成できる確率が著しく減少してしまうという不都合もある。

【０００８】また、上記アローマップ表示、等磁線表示の何れも特定のタイミングにおける生体磁場測定値、即ち分布を可視的に表示するものであり、動的な生体磁場測定値の表示には不適切である。さらに詳細に説明すると、アローマップ表示により動的に電流素片を表示することは可能であるが、一般的に臓器における電流素片の数は、体積電流を表示するのに十分な数に設定しなければならない。即ち、著しく多数の電流素片がベクトル表示されなければならない。そして、これら全ての電流素片の向き、大きさが時々刻々と変化するのであるから、ＭＲＩ画像とオーバーラップ表示された矢印を見ても、例えば、臓器の興奮電流の伝播状態を簡単には把握できないという不都合がある。

【０００９】コンターマップ表示を動的な生体磁場測定値の表示に適用しても、等磁線はもともと個々の電流素片の表示には不向きであるから、到底臓器の興奮電流の伝播状態の把握のために採用することはできない。

【００１０】

【発明の目的】この発明は上記の問題点に鑑みてなされたものであり、所定間隔毎の断層像に基づいてきめ細かい像データを得ることができる新規な断層像処理方法およびその装置を提供することを第１の目的とし、断層像処理方法により得られたきめ細かい像データに基づいて簡単にかつ正確に生体磁場源の解析を行なうことができる生体磁場測定方法およびその装置を提供することを第２の目的とし、動的な生体物理量測定値を把握し易い状態で表示できる生体物理量計測結果表示方法およびその装置を提供することを第３の目的としている。

【００１１】

【課題を解決するための手段】上記第１の目的を達成するための、請求項１の断層像処理方法は、所定間隔毎の断層像に基づいて補間演算を行なって立体像データを得、処理対象となる空間を所定の小立体領域に区分して各小立体領域に含まれる立体像データを計数し、計数値に基づいて小立体領域を２値化する方法である。

【００１２】請求項２の断層像処理装置は、所定間隔毎の断層像に基づいて補間演算を行なって立体像データを得る断層像補間手段と、処理対象となる空間を所定の小立体領域に区分する空間区分手段と、区分された各小立体領域に含まれる立体像データを計数する立体像データ

5　　6

計数手段と、計数値に基づいて小立体領域を２値化する２値化手段とを含んでいる。

【００１３】上記第２の目的を達成するための、請求項３の生体磁場測定方法は、請求項１の断層像処理方法により得られた小立体領域の頂点の位置情報に基づいて異なる磁場源情報に基づく複数のビオ・サバールの法則の演算を行ない、各演算結果を累積加算して得られる磁場演算値と測定した磁場計測値との差を算出し、算出した差に基づいて各演算式に含まれる磁場源情報を補正し、差が十分に小さくなるまで上記一連の処理を反復してから各演算式に含まれる磁場源情報を生体磁場測定結果として出力する方法である。

【００１４】請求項４の生体磁場測定方法は、算出した差に基づく補正に代えて、各小立体領域の各頂点の各座標成分の修正量を算出し、各座標成分の修正量の符号に基づいて修正対象頂点を得るとともに、各座標成分の修正量に基づいて、得られた修正対象頂点に対して磁場源情報推定値の再配分を行なう処理を採用する方法である。

【００１５】請求項５の生体磁場測定装置は、請求項１の断層像処理方法により得られた小立体領域の頂点の位置情報に基づいて異なる磁場源情報に基づく複数のビオ・サバールの法則の演算を行なう演算手段と、各演算手段から出力される演算結果を累積加算する累積加算手段と、累積加算手段から出力される累積加算結果と磁場計測値とを入力として誤差を算出する誤差算出手段と、算出誤差に基づいて各演算手段における磁場源情報の補正を行なう補正手段と、補正手段による補正が施された結果を収集して生体磁場測定結果として出力する補正結果収集手段とを含んでいる。

【００１６】請求項６の生体磁場測定装置は、補正手段として、各小立体領域の各頂点の各座標成分の修正量を算出する修正量算出手段と、各座標成分の修正量の符号に基づいて修正対象頂点を抽出する修正対象頂点抽出手段と、各座標成分の修正量に基づいて、得られた修正対象頂点に対して磁場源情報推定値の再配分を行なう再配分手段とを含むものを用いている。

【００１７】上記第３の目的を達成するための、請求項７の生体磁場測定結果表示方法は、生体内の複数の点のそれぞれに対応する生体物理量計測値の絶対値に基づいて単位図形のサイズを設定し、生体構造参照像を表示するとともに、生体構造参照像の該当位置に設定されたサイズの単位図形を表示する方法である。請求項８の生体磁場測定結果表示方法は、円からなる単位図形を表示するものである。

【００１８】請求項９の生体磁場測定結果表示装置は、生体内の複数の点のそれぞれに対応する生体物理量計測値の絶対値に基づいて単位図形のサイズを設定する単位図形サイズ設定手段と、生体構造参照像を表示する生体像表示手段と、生体構造参照像の該当位置に設定されたサイズの単位図形を表示する単位図形表示手段とを含でいる。請求項１０の生体磁場測定結果表示装置は、円からなる単位図形を表示するものである。

【００１９】

【作用】請求項１の断層像処理方法であれば、所定間隔毎の断層像に基づいて補間演算を行なって立体像データを得、処理対象となる空間を所定の小立体領域に区分して各小立体領域に含まれる立体像データを計数し、計数値に基づいて小立体領域を２値化するのであるから、所定間隔毎の断層像しか得られていなくても、補間演算を行なうことにより全空間に対応して立体像データを得、しかも区分された小立体領域に含まれる立体像データの数に基づいて小立体領域を２値化することにより単純化された立体像を得ることができる。したがって、可視的に表示した場合に、臓器等に相当する箇所、空間に相当する箇所を簡単に認識できる。

【００２０】尚、上記補間演算としては、直線補間演算、スプライン補間演算等から適宜選択された補間演算を採用すればよい。また、小立体領域を２値化する場合における立体像データの数についても断層像の種類、対象臓器等に適合させるべく適宜閾値を設定すればよい。さらに、小立体領域としては、空間を密に充填し得る立体領域であればよいが、後処理の簡素化等を考慮すれば、立方体領域であることが最も好ましい。

【００２１】請求項２の断層像処理装置であれば、所定間隔毎の断層像に基づいて断層像補間手段により補間演算を行なって立体像データを得る。また、空間区分手段により、処理対象となる空間を所定の小立体領域に区分しておく。そして、立体像データ計数手段により、区分された各小立体領域に含まれる立体像データを計数し、２値化手段により、計数値に基づいて小立体領域を２値化する。可視的に表示した場合に、臓器等に相当する箇所、空間に相当する箇所を簡単に認識できる。請求項３の生体磁場測定方法であれば、請求項１の断層像処理方法により得られた小立体領域の頂点の位置情報に基づいて異なる磁場源情報に基づく複数のビオ・サバールの法則の演算を行ない、各演算結果を累積加算して得られる磁場演算値と測定した磁場計測値との差を算出し、算出した差に基づいて各演算式に含まれる磁場源情報を補正し、差が十分に小さくなるまで上記一連の処理を反復してから各演算式に含まれる磁場源情報を生体磁場測定結果として出力するのであるから、複数のビオ・サバールの法則の演算結果の累積加算値が磁場計測値と高精度に近似されるまで補正を行なうことにより、各小立体領域の頂点における磁場源情報を得ることができる。また、小立体領域の頂点の位置情報は既知であるから、推定すべき未知数の数を大幅に低減できる。

【００２２】請求項４の生体磁場測定方法であれば、各小立体領域の各頂点の各座標成分の修正量を算出し、各座標成分の修正量の符号に基づいて修正対象頂点を得る

とともに、各座標成分の修正量に基づいて、得られた修正対象頂点に対して磁場源情報推定値の再配分を行なうことにより、算出した差に基づく補正を行なうのであるから、互に近接する状態で割り当てられた、大きさが互に等しくかつ向きが互に逆の磁場源ベクトルが存在していても、これらを確実に補正でき、一層高精度に推定された磁場源情報を得ることができる。また、隣接する頂点間で再配分を行なうことにより推定を行なうのであるから、推定対象となる磁場源情報の数に見合って従来必要とされていた測定点数よりも少ない測定点に基づいて高精度の磁場源推定を達成できる。

【００２３】請求項５の生体磁場測定装置であれば、請求項１の断層像処理方法により得られた小立体領域の頂点の位置情報に基づいて、演算手段により異なる磁場源情報に基づく複数のビオ・サバールの法則の演算を行なって、累積加算手段により、各演算手段から出力される演算結果を累積加算する。そして、累積加算手段から出力される累積加算結果と磁場計測値とに基づいて誤差算出手段により誤差を算出し、算出誤差に基づいて補正手段により各演算手段における磁場源情報の補正を行なう。補正手段による補正処理を必要回数だけ行なった後に、補正結果収集手段により、補正手段による補正が施された結果を収集して生体磁場測定結果として出力することにより、各小立体領域の頂点における磁場源情報を得ることができる。また、小立体領域の頂点の位置情報は既知であるから、推定すべき未知数の数を大幅に低減でき、装置全体として構成を簡素化できる。

【００２４】請求項６の磁場源測定装置であれば、補正量算出手段により各小立体領域の各頂点の各座標成分の修正量を算出し、各座標成分の修正量の符号に基づいて修正対象頂点抽出手段により修正対象頂点を抽出し、再配分手段により、各座標成分の修正量に基づいて、得られた修正対象頂点に対して磁場源情報推定値の再配分を行なうことにより、算出した差に基づく補正を行なうのであるから、互に近接する状態で割り当てられた、大きさが互に等しくかつ向きが互に逆の磁場源ベクトルが存在していても、これらを確実に補正でき、一層高精度に推定された磁場源情報を得ることができる。また、隣接する頂点間で再配分を行なうことにより推定を行なうのであるから、推定対象となる磁場源情報の数に見合って従来必要とされていた測定点数よりも少ない測定点に基づいて高精度の磁場源推定を達成できる。

【００２５】生体磁場測定方法についてさらに詳細に説明すると、本件発明者が生体磁場の測定に関して鋭意研究を重ねた結果、次のことを見出した。各小立体領域の各頂点は断層像処理方法により得られているのであるから、座標値は既知である。したがって、各頂点における磁場源情報を得るために必要な情報は電流素片のベクトル成分のみである。

【００２６】また、１つの小立体領域の１つの頂点は、隣合う他の小立体領域の頂点を兼ねているのであるから、小立体領域の数が増加しても、頂点数が小立体領域の増加に比例して増加することはなく、小立体領域の数が十分に大きければ、頂点数と小立体領域の数はほぼ等しくなる。さらに、１つの頂点の電流素片は近接する他の電流素片と相関があるので、１つの頂点の電流素片当りの情報量は一般的な未知数量の推定を行なう場合と比較して著しく少なくできる。

【００２７】さらにまた、磁場源でない頂点における電流素片は０ベクトルに収束するので、最終的に推定を行なわなければならない電流素片の数は著しく少なくなる。請求項３から請求項６の発明は上記の知見に基づいてなされたものであり、測定開始時点においては未知の電流素片（数も未知）の推定を行なうに当って、未知の電流素片数を考慮することなく、計測システムの能力、容量等に基づいて定まる所定数の磁場計測値を得、所定数の磁場計測値に基づいて磁場源情報の補正処理を反復することにより未知の電流素片の高精度の推定を達成でき、推定結果を生体磁場測定結果として採用できる。

【００２８】請求項７の生体磁場測定結果表示方法であれば、生体磁場測定結果を生体構造参照像と共に表示するに当って、生体内の複数の点のそれぞれに対応する生体磁場測定値の絶対値に基づいて単位図形のサイズを設定し、生体構造参照像を表示するとともに、生体構造参照像の該当位置に設定されたサイズの単位図形を表示するのであるから、矢印の方向と長さで磁場測定結果を表示する場合と比較して、例えば、最大の生体磁場測定結果の分布状態を簡単に認識できる。但し、生体磁場の方向成分に関しては把握できないことになるが、生体磁場測定結果を動的に表示すれば、例えば、最大の生体磁場測定結果の分布状態の時間的変動を簡単に認識できるのであるから、特に不都合はない。生体磁場測定結果の表示が最も意味を持つ医療解析においては、一般に最大の生体磁場測定結果の分布および時間的変動を簡単に把握できることが要望されるのであるから、この生体磁場測定結果表示方法はこの要望に最適の方法である。

【００２９】請求項８の生体磁場測定結果表示方法であれば、請求項７の作用に加え、単位図形が円であるから、単位図形同士の隙間をかなり大きくでき、背景となる生体構造参照像の把握が容易になる。請求項９の生体磁場測定結果表示装置であれば、生体磁場測定結果を生体構造参照像と共に表示するに当って、生体内の複数の点のそれぞれに対応する生体磁場測定値の絶対値に基づいて単位図形サイズ設定手段により単位図形のサイズを設定し、生体像表示手段により生体構造参照像を表示するとともに、単位図形表示手段により生体構造参照像の該当位置に設定されたサイズの単位図形を表示するのであるから、矢印の方向と長さで磁場測定結果を表示する場合と比較して、例えば、最大の生体磁場測定結果の分布状態を簡単に認識できる。但し、生体磁場の方向成分

に関しては把握できないことになるが、生体磁場測定結果を動的に表示すれば、例えば、最大の生体磁場測定結果の分布状態の時間的変動を簡単に認識できるのであるから、特に不都合はない。生体磁場測定結果の表示が最も意味を持つ医療解析においては、一般に最大の生体磁場測定結果の分布および時間的変動を簡単に把握できることが要望されるのであるから、この生体磁場測定結果表示装置はこの要望に最適の装置である。

【００３０】請求項１０の生体磁場測定結果表示装置であれば、請求項９の作用に加え、単位図形が円であるから、単位図形同士の隙間をかなり大きくでき、背景となる生体構造参照像の把握が容易になる。

【００３１】

【実施例】以下、実施例を示す添付図面によって詳細に説明する。図１はこの発明の断層像処理方法の一実施例を説明するフローチャートであり、ステップＳＰ１において断層像が与えられるまで待ち、ステップＳＰ２において、与えられた断層像に基づく補間処理を行なって補間断層像を得、ステップＳＰ３において、与えられた断層像および補間断層像を予め設定されたサイズの正方形に量子化し、ステップＳＰ４において、量子化された正方形の中心を中心とし、かつ１辺が正方形の１辺と等しい立方体を得、ステップＳＰ５において、何れかの立方体について、与えられた断層像を構成する画素および補間断層像を構成する画素の数を計数し、ステップＳＰ６において計数値が予め設定されている閾値（例えば、全平均値の平均値）よりも大きいか否かを判別する。そして、計数値が閾値よりも大きいと判別された立方体については、ステップＳＰ７において表示されるべき立方体（以下、表示立方体と称する）に割り当て、逆にステップＳＰ６において計数値が閾値よりも大きくないと判別された立方体については、ステップＳＰ８において表示されない立方体（以下、非表示立方体と称する）に割り当てる。ステップＳＰ７またはステップＳＰ８の処理が行なわれた後は、ステップＳＰ９において全ての立方体について処理が完了したか否かを判別し、処理が行なわれていない立方体が存在すると判別された場合には、ステップＳＰ１０において他の立方体を選択し、再びステップＳＰ５の処理を行なう。また、ステップＳＰ９において全ての立方体について処理が完了したと判別された場合には、ステップＳＰ１１において、表示立方体に割り当てられた立方体のみを可視的に表示して一連の処理を終了する。

【００３２】但し、立方体に含まれる画素数に代えて、立方体中の全画素数に対する断層像画素数の割合および対応する閾値を採用してもよいことはもちろんである。図２から図４を参照しながら断層像処理方法をさらに説明する。図２は断層像の一例を示す概略図であり、ぬりつぶし表示された部分が人体の臓器を示している。図２に示す断層像について量子化された正方形の中心が小さいドットで示されるように与えられるので、与えられたドットを中心とする立方体が定まることになる。そして、定められた立方体に含まれる画素数が閾値よりも大きい場合には図３に平面視して示すように表示立方体と非表示立方体とに割り当てられる。図４は図３に対応する斜視図であり、表示立方体に割り当てられた立方体のみが表示されている。したがって、表示された立方体を見ることにより、臓器の立体形状を簡単に把握できる。

【００３３】尚、この一連の処理を全ての断層像および補間断層像について行なうことにより、生体臓器をソリッド・モデルとして可視的に表示できる。但し、磁場源解析結果を重畳表示する場合には、磁場源解析結果を確認し易くするために、表示立方体に割り当てられた立方体を半透明表示することが好ましい。また、断層像中における各臓器を指定することにより、該当する臓器のみの表示、複数の臓器の色分け表示をも簡単に達成できる。さらに、非表示立方体は臓器の空洞等に対応するのであるから、後述する生体磁場源解析等に当っては表示立方体のみについて処理を行なえばよくなり、後処理に必要な演算負荷を大幅に低減できる。

【００３４】

【実施例２】図５はこの発明の断層像処理装置の一実施例を示すブロック図であり、複数の断層像を保持する断層像保持部１と、断層像保持部１から処理対象となる断層像を選択する第１断層像選択部２と、選択された断層像に基づく補間処理を行なって補間断層像を得る断層像補間部３と、補間断層像を保持する補間断層像保持部４と、断層像選択部２および断層像補間部３を必要回数だけ反復動作させる第１反復制御部５と、第１反復制御部５による反復動作制御が終了したことに応答して、断層像保持部１または補間断層像保持部４から順次断層像を選択する第２断層像選択部６と、選択された断層像に対応して立方体を割り当てる立方体割り当て部７と、割り当てられた立方体中に存在する画素数を計数する画素数計数部８と、計数された画素数が所定の閾値よりも大きいか否かを判別する判別部９と、画素数が所定の閾値よりも大きいことを示す判別部９の判別結果に応答して該当する立方体を表示立方体に割り当てる表示立方体割当部１０と、画素数が所定の閾値よりも大きくないことを示す判別部９の判別結果に応答して該当する立方体を非表示立方体に割り当てる非表示立方体割当部１１と、断層像、補間断層像に対応して立方体の割当結果を保持する割当結果保持部１２と、第２断層像選択部６、立方体割当部７、画素計数部８、判別部９、表示立方体割当部１０および非表示立方体割当部１１を必要回数だけ反復動作させる第２反復制御部１３と、第２反復制御部１３により反復動作制御が終了したことに応答して表示立方体に割り当てられた立方体のみを可視的に表示する立方体表示部１４とを有している。

【００３５】したがって、図５の構成の断層像処理装置

を採用することにより、図２から図４に示す断層像の処理および表示立方体に割り当てられた立方体のみに基づく可視的表示を達成できる。

【００３６】

【実施例３】図６はこの発明の生体磁場測定装置の一実施例を示すブロック図であり、複数個の、ピオ・サバール演算ユニット１１１，１１２，・・・，１１ｍと、ピオ・サバール演算ユニット１１１，１１２，・・・，１１ｍから出力される演算結果を累積加算するシグマ・ユニット２０と、シグマ・ユニット２０から出力される累積加算結果Ｏｊ（ｔ）と教師パターンとしての磁場計測値Ｓｊ（ｔ）とを入力として両者の差を算出する誤差演算器３０と、算出された差に基づいて、ピオ・サバール演算ユニット１１１，１１２，・・・，１１ｍにおいて推定されている電流素片のベクトル成分を補正する補正部１１１ａ，１１２ａ，・・・，１１ｍａと、ピオ・サバール演算ユニット１１１，１１２，・・・，１１ｍにおいて推定されている電流素片のベクトル成分を収集して解析結果として出力する情報収集ユニット４０とを有している。尚、上記ピオ・サバール演算ユニット１１１，１１２，・・・，１１ｍは、時刻ｔ、図１の断層像処理方法もしくは図５の断層像処理装置により得られた、表示立方体に割り当てられた立方体の頂点の位置情報が既知情報として供給されたことに応答して、既知情報に基づいて各ピオ・サバール演算ユニットに設定されている、ピオ・サバールの法則の演算を行なうとともに、誤差演算器３０から出力される推定誤差ｄｊ（ｔ）｛＝Ｓｊ（ｔ）－Ｏｊ（ｔ）｝が供給されたことに応答して演算式に含まれる暖流素片のベクトル成分を推定誤差が少なくなるように補正する。また、ピオ・サバール演算ユニット１１１，１１２，・・・，１１ｍはそれぞれ同期的に動作するように制御してもよく、また、非同期的に動作するように制御してもよい。

【００３７】上記の構成の生体磁場測定装置の作用は次のとおりである。解析対象となる磁場Ｏｊ（ｔ）は、時刻ｔと各小立方体の頂点の３次元座標値ｘｉ，ｙｉ，ｚｉ（ｉは正の整数、以下同じ）および電流素片のベクトル成分Ｐｘｉ，Ｐｙｉ，Ｐｚｉを持つ関数ｇｉ（ビオ・サバールの法則に基づいて定まる関数）の線形和である。但し、磁場センサとして平面内のベクトル成分のみを計測可能なものを使用する場合には、座標系をセンサに適合させることにより何れかのベクトル成分をオミットできる。また、各小立方体は図１の断層像処理方法または図５の断層像処理装置により得られているのであるから、３次元座標値は全て既知の値である。

【００３８】したがって、時刻ｔおよび各小立方体の各頂点の３次元座標値をｍ個のピオ・サバール演算ユニット１１１，１１２，・・・，１１ｍに供給してそれぞれ関数ｇ１，ｇ２，・・・，ｇｍの演算を行なって関数値を算出し、算出された全ての関数値をシグマ・ユニット２０に供給することにより累積加算値Ｏｊ（ｔ）を得ることができる。但し、当初は各電流素片のベクトル成分が適当に設定されているのであるから、得られる累積加算値Ｏｊ（ｔ）は実際の計測値Ｓｊ（ｔ）とは異なる。したがって、誤差演算器３０において実際の計測値Ｓｊ（ｔ）と累積加算値Ｏｊ（ｔ）との差を算出し、算出された差を推定誤差ｄｊ（ｔ）としてピオ・サバール演算ユニット１１１，１１２，・・・，１１ｍの補正部１１１ａ，１１２ａ，・・・，１１ｍａにフィードバックし、推定誤差ｄｊ（ｔ）が小さくなるように各ピオ・サバール演算ユニットのベクトル成分を変化させる。

【００３９】上記一連の処理を反復すれば推定誤差ｄｊ（ｔ）が小さくなり、ついには推定誤差ｄｊ（ｔ）がほぼ０になるので、この時点においてピオ・サバール演算ユニットのベクトル成分の値を情報収集ユニット４０により収集して出力することにより各小立方体の各頂点における電流素片のベクトル成分を得ることができる。また、推定誤差評価関数Ｅｊ（ｔ）を次式で定義すれば、数１が得られる。

Ｅｊ（ｔ）＝（１／２）｛Ｓｊ（ｔ）－Ｏｊ（ｔ）｝^{2}

【００４０】

【数１】

$$\partial Ej(t)/\partial Oj(t) = -\{Sj(t) - Oj(t)\}$$

【００４１】そして、各ピオ・サバール演算ユニットにおけるベクトル成分の補正を最急降下法に基づいて行なうこととすれば、、推定誤差評価関数が最小になるベクトル成分の推定は数２に基づいて行なうことができる。

【００４２】

【数２】

$$aik = aik - \varepsilon k\{\partial Ej(t)/\partial aik\}$$
$$= aik - \varepsilon k\{(\partial Ej(t)/\partial Oj(t))\{\partial Oj(t)/\partial aik\} = aik + \varepsilon k\{Sj(t) - Oj(t)\}\{\partial Oj(t)/\partial aik\}$$

但し、εｋはベクトル成分ａｉｋの学習ゲイン（補正ゲイン）である。

【００４３】また、累積加算値Ｏｊ（ｔ）のａｉｋによる偏微分値は数３で与えられるので、数２は数４と表現できる。

【００４４】

【数３】

13 14

$$\partial Oj(t)/\partial aik=\partial\{\sum_{i=1}^{m} gi(t, ai1, ai2, ai3, \cdots aiL)\}/\partial aik$$
$$=\partial\{gi(t, ai1, ai2, ai3, \cdots aiL)\}/\partial aik$$

【0045】

【数4】

$$aik=alk+\varepsilon k\{Sj(t)-Oj(t)\}[\partial\{gi(t, ai1, ai2, ai3, \cdots aiL)\}/\partial aik]$$

【0046】したがって、数4の処理を行なうことによりベクトル成分の推定精度を高め、より正確なベクトル成分を得ることができる。尚、推定誤差ｄｊ（ｔ）の傾きが正の場合には補正値を負に、推定誤差ｄｊ（ｔ）の傾きが負の場合には補正値を正に設定すればよい。以上のようにして各頂点の電流素片のベクトル成分が得られれば、８頂点における電流素片に基づいてベクトルの空間補間処理を行なって各微小点が発生する磁束密度を得、各微小点が発生する磁束密度を積分することにより、各小立方体が発生する磁界を得ることができる。したがって、得られた結果に基づいて分布電流を霧状に表示でき、または矢印によるアロー図で表示できる。

【0047】また、図６の装置に基づく処理は図１または図５の実施例により得られた小立方体（表示立方体に割り当てられた小立方体）のみに基づいて行なえばよいのであるから、臓器等を対象とする場合に、臓器の内部空洞部分等は当初から処理対象に含まれないことになり、処理負荷を低減できる。また、各小立方体の各頂点はかなり高い確率で他の小立方体の頂点を兼ねているのであるから、小立方体の数が増加割合に比して処理対象となる頂点数の増加割合が小さくなり、この点からも処理負荷を低減できる。

【0048】さらに、磁場計測値を得るための測定点数については、一般的な逆問題の解析を行なう場合に未知数の数よりも多い数の測定点が要求されると思われていたのであるが、比較的少ない測定点数で十分なベクトル成分の推定を達成できることを見出した。したがって、測定点数を比較的少なくできることに伴なって全体としての処理負荷を低減できることになる。

【0049】この点についてさらに詳細に説明する。従来は臓器等を小立方体の集合として定義することは全く行なわれておらず、したがって、例えば、推定すべき電流素片の数よりも少なくない測定点が必要であった。この結果、電流素片の数が定まっていなければ、十分な安全性を見込んで測定点数を設定していた。具体的には、臓器に流れる電流は時間の経過に伴なって位置および向き、大きさが変化するのであるから、電流素片の数は膨大にならざるを得ない。しかし、この実施例においては、各小立方体の位置が予め固定されているのであるから、測定点に影響を及ぼさない小立方体における電流素片は０ベクトルに収束してしまうことになる。そして、０ベクトルに収束した電流素片については以後の推定処理が不要になるのであるから、比較的少ない測定点で得られる磁場計測値のみに基づいて高精度のベクトル成分の推定を達成できる。

【0050】

【実施例３】図７はこの発明の生体磁場測定装置の他の実施例を示すブロック図、図８は１つの階層型パーセプトロンに対応する部分の構成を詳細に示す概略図であり、多入力１出力の複数個の階層型パーセプトロン１０ｐ（ｐ＝１，２，・・・，ｍ）と、階層型パーセプトロン１０ｐからの閾数値出力ｇｉｊを累積加算するシグマ・ユニット２００と、シグマ・ユニット２００から出力される累積加算結果Ｏｊ（ｔ）と教師パターンとしての計測値Ｓｊ（ｔ）とを入力として両者の差を算出する閾数値誤差演算器３００と、各階層型パーセプトロン１０ｐからの閾数値出力ｇｉｊに対応する偏微分値を算出する偏微分値算出部１０ｐｒ（ｒ＝１，２，・・・ｎ）と、各階層型パーセプトロン１０ｐの偏微分値算出部１０ｐｒからの出力と数値微分法等により予め算出されている偏微分値（偏微分値教師パターン）とを入力として両者の差を算出する偏微分値誤差演算器３０ｐｒと、閾数値誤差演算器３００により算出される差および偏微分値誤差演算器３０ｐｒにより算出される差に基づいて該当する階層型パーセプトロン１０ｐに偏微分閾数の学習を行なわせる偏微分閾数学習部６０ｐと、閾数値誤差演算器３００により算出された累積加算結果Ｏｊ（ｔ）と教師パターンとしての計測値Ｓｊ（ｔ）との差および偏微分値算出部１０ｐｒにより算出された偏微分値に基づいて階層型パーセプトロン１０ｐの入力層における入力を補正する補正部１２ｐと、補正部１２ｐと偏微分閾数学習部６０ｐとを選択するとともに、選択された補正部１２ｐまたは偏微分閾数学習部６０ｐを所定回数（差を十分に小さくできる回数）だけ反復動作させる制御部４００と、補正部１２ｐにより補正が所定回数だけ反復されたことを条件として各階層型パーセプトロン１０ｐの未知のベクトル成分に対応する入力を未知数量推定結果として出力する情報収集ユニット５００とを有している。 尚、上記各階層型パーセプトロン１０ｐは、既知の入力パターンおよび対応する教師パターンを与えて十

分にビオ・サバールの法則に基づく関数の学習を行なったものである。また、階層型パーセプトロン１０ｐはそれぞれ同期的に動作するように制御してもよく、また、非同期的に動作するように制御してもよい。

【００５１】また、偏微分関数学習部６０ｐは、例えば、関数値誤差演算器３００により算出される差に基づく階層型パーセプトロン１０ｐの学習（例えば、バックプロパゲーション学習）および偏微分値誤差演算器３０ｐにより算出される差に基づく階層型パーセプトロン１０ｐの学習を交互に反復させるものであり、関数の学習結果を余り損なうことなく偏微分関数の学習を行なわせることができる。

【００５２】さらに、補正部１２ｐはそれぞれ複数の補正部を有しており、関数値誤差演算器３００により算出された差および偏微分値算出部１０ｐｋにより算出された差を入力として該当する未知数量を補正する。上記の構成の未知数量推定装置の作用は次のとおりである。各階層型パーセプトロン１０ｐにおいてビオ・サバールの法則に基づく学習が完了しているのであるから、未知のベクトル成分に対応する既知の入力の何れか１つを微小量だけ変化させて出力パターンを得るとともに、偏微分値算出部１０ｐｒにより対応する偏微分値を得る。尚、未知のベクトル成分に対応する既知の入力を微小量だけ変化させた場合における偏微分値を数値微分法等により予め算出して偏微分値教師パターンとして与えておく。この状態において制御部４０により偏微分関数学習部６０ｐを選択し、選択した偏微分関数学習部６０ｐを所定回数だけ反復動作させることにより再びバックプロパゲーション学習を行ない、ビオ・サバールの法則に基づく関数およびこの関数の偏微分関数の演算と等価な処理を達成できるように各階層型パーセプトロン１０ｐを構成するニューロン素子の荷重、閾値を決定する。

【００５３】尚、何れかの階層型パーセプトロン１０ｐにより得られた学習結果としての荷重、閾値を他の階層型パーセプトロンの荷重、閾値としてそのまま採用すれば、他の階層型パーセプトロンについては関数の学習および偏微分関数の学習を共に不要にでき、学習所要時間を大幅に短縮できる。以上のようにして必要な学習が完了した後は、偏微分関数学習部６０Ｐに代えて制御部４００により補正部１２ｐを選択するとともに情報収集ユニット５００を動作させればよく、図６の実施例と同様にベクトル成分を精度よく推定できる。

【００５４】

【実施例４】図９はこの発明の生体磁場測定方法のさらに他の実施例を示すブロック図であり、図７および図８の実施例と異なる点は、図７の実施例において階層型パーセプトロン毎に設けられている偏微分値算出部１０ｐｒに代えて、１入力のみを微小量だけ変化させる入力変化部１５ｐと、１入力の変化前後における出力を保持する出力保持部１６ｐと、両出力の差を算出する差算出部１７ｐを設けた点のみである。

【００５５】したがって、この実施例の場合には、偏微分演算を行なわなくても、１入力のみの微小変化に対応する出力変化を算出でき、この出力変化が偏微分値に相当するのであるから、上記実施例と同様の作用を達成できる。また、この実施例では偏微分関数の学習が不要になるので、学習所要時間を大幅に短縮できる。

【００５６】

【実施例５】図１０はこの発明の磁場源測定装置のさらに他の実施例を示すブロック図であり、１ユニット分のみを示している。複数個の、ビオ・サバールの法則の演算を行なうビオ・サバール演算ユニット１１ｉと、ビオ・サバール演算ユニット１１ｉにおいて推定されている電流素片のベクトル成分を収集して解析結果として出力する電流素片収集ユニット４０ａと、図１の方法または図５の装置により得られた３次元座標値を基準として修正量Δｘ，Δｙ，Δｚを算出する修正量算出部４１ｉと、算出された修正量Δｘ，Δｙ，Δｚの符号に基づいて、推定されている電流素片のベクトル成分の再配分対象となる隣接頂点を抽出する頂点抽出部４２ｉと、修正量Δｘ，Δｙ，Δｚに基づいて定まる修正ベクトルを正規化する正規化部４３ｉと、正規化された修正ベクトルの各成分の絶対値に基づいて再配分比率を算出する再配分比率算出部４４ｉと、推定されている電流素片のベクトル成分および算出された再配分比率に基づいて抽出された頂点に関して推定されている電流素片のベクトル成分に推定値の再配分を行なう再配分部４５ｉと、再配分部４５ｉにより再配分された再配分値に基づいて該当する電流素片のベクトル成分の推定値を更新する推定値更新部４６ｉと、全ての頂点について修正量Δｘ，Δｙ，Δｚが十分に小さくなるまでビオ・サバール演算ユニット１１ｉ、修正量算出部４１ｉ、頂点抽出部４２ｉ、正規化部４３ｉ、再配分比率算出部４４ｉ、再配分部４５ｉおよび推定値更新部４６ｉの処理を反復させる反復制御部４７とを有している。

【００５７】尚、上記推定値更新部４６ｉにおいては、複数の隣接頂点から配分を受ける場合に、各隣接頂点からの再配分比率の加算を行なうのではなく、全ての再配分比率の平均値を算出して現在の値（他の隣接頂点に再配分した残りの割合）に加算することにより新たな推定値を得るようにしている。上記修正量算出部４１ｉは、例えば、ビオ・サバール演算ユニットにより算出された関数値の偏微分値を算出することにより修正量Δｘ，Δｙ，Δｚを得るものである。

【００５８】上記の構成の生体磁場測定装置の作用は次のとおりである。各ビオ・サバール演算ユニットにおいては、

$$gij=(\mu 0/4\pi)\{(Yj\times pxi-Xj\times pyi)/Rji^{3}\}$$

の演算を行なう。ここで、$\mu 0$は透磁率を示し、ｉ（ｉ

＝1，2，・・・，N）は各小立方体の各頂点における電流素片を、j（j＝1，2，・・・，m）は測定点をそれぞれ示し、測定点の計測条件をPj＝（xj，yj，zj）、電流素片の未知の物理量をUi＝（xi，yi，zi，pxi，pyi）とした場合にXji＝xj－xi、Yji＝yj－yi、Zji＝zj－ziであり、Rji＝$(Xji^2+Yji^2+Zji^2)^{1/2}$である。

$$\frac{\partial gij}{\partial xi}=\frac{\mu 0}{4\pi}\left\{\frac{3Xji\,(Yji\,Pxi-Xji\,pyi)+Rji^2\,pyi)}{Rji^5}\right\}$$

【0061】

$$\frac{\partial gij}{\partial yi}=\frac{\mu 0}{4\pi}\left\{\frac{3Yji\,(Yji\,Pyi-Xji\,pxi)-Rji^2\,pxi)}{Rji^5}\right\}$$

【0062】

$$\frac{\partial gij}{\partial zi}=\frac{\mu 0}{4\pi}\left\{\frac{3Zji\,(Yji\,Pxi-Xji\,pyi)}{Rji^5}\right\}$$

【0063】

$$\frac{\partial gij}{\partial Pxi}=\frac{\mu 0}{4\pi}\,\frac{Yji}{Rji^3}$$

【0064】

$$\frac{\partial gij}{\partial Pyi}=\frac{\mu 0}{4\pi}\,\frac{Xji}{Rji^3}$$

【0065】即ち、数5から数7の偏微分演算とSj－Ojに基づいて修正量Δx，Δy，Δzを得ることができる。修正量Δx，Δy，Δzが得られれば、頂点抽出部421により、算出された修正量Δx，Δy，Δzの符号に基づいて、推定されている電流素片のベクトル成分の再配分対象となる隣接頂点を抽出する。具体的には、図11に破線で示すように修正ベクトルが得られるのであるから、二重丸で示される頂点が再配分対象となる隣接頂点として抽出される。そして、正規化部433iにより修正ベクトルを正規化し、正規化された修正ベクトルの各成分の絶対値に基づいて再配分比率算出部441により再配分比率を算出し、再配分部451iにより、推定されている電流素片のベクトル成分および頂点抽出部421により抽出された頂点に関して推定されている電流素片のベクトル成分に推定値の再配分を行なう。この場合において、各電流素片のベクトル成分は複数の修正ベクトルに基づく再配分が行なわれる可能性があるが、これらを単純に加算すると再配分前の値と再配分後の値とが大幅に異なり、推定の安定性を損なう危険性があるので、推定値更新部461において、該当する現在の推定値（他の推定値に配分して残りの割合）に対して再配分値の平均（複数の修正ベクトルに基づく再配分比率の平均）を加算することにより新たなベクトル成分推定値を得るようにしている。

【0066】以下、全ての頂点について修正量Δx，Δy，Δzが十分に小さくなるまで反復制御部47によりビオ・サバール演算ユニット111、座標値収集ユニット40a、修正量算出部411、頂点抽出部421、正規化部433i、再配分比率算出部441、再配分部451および推定値更新部461の処理を反復させることにより高精度の電流素片の推定を達成できる。尚、反復制御部47により推定処理を反復させる場合において、各小立方体の各頂点の3次元座標値は固定されているのであるから、上記修正量Δx，Δy，Δzが直接数5，数6，数7に反映されることはないが、電流素片のベクトル成分は再配分処理により変更されるのであるから、ベクトル成分を通して間接的に反映されることになる。即ち、数5、数6、数7、数8および数9におけるXji，Yji，Zji，Rjiは推定開始当初から推定終了まで変化せず、pxi，pyiのみが変化し、最終的に高精度に推定されたpxi，pyiを得ることができる。この結果、例えば図12（A）に示すように、互にキャンセルし合う電流素片が互に近接する位置に割り当てられていても、再配分処理を行なうことにより図12（B）に示すように推定が行なわれ、電流が存在していない位置に互にキャンセルし合う電流が残留するという不都合を確実に解消できる。尚、図12中、黒丸が処理対象頂点を、白丸が隣接する頂点を示している。

【0067】図14から図18は1チャネルのマグネトメータを用いて3cm間隔、6×6点で計測された心磁図を心電図を用いて同期加算して得た磁界分布図に基づいてQ波近傍時刻の磁場源推定結果を示す図であり、医学的に確認されている心臓の体積電流に高精度に近似できる推定結果が得られていることが分る。尚、図13はMRI画像に基づいて得られた深さが6cmの頂点情報であり、図14から図18はそれぞれR波出現前35msec、33msec、30msec、25msec、20msecの時刻に対応

する推定結果であり、大きい黒丸が心臓の壁を示しているとともに、黒丸を起点とする線分で電流素片を示している。

【００６８】尚、この実施例において、各ビオ・サバール演算ユニットに代えて階層型パーセプトロンを採用することが可能である。

【００６９】

【実施例７】図１９はこの発明の生体磁場測定結果表示方法の一実施例を説明するフローチャートであり、ステップＳＰ１において、生体断層像に対応する平面内における、所定の時点における電流素片の位置および大きさ（興奮電流の絶対値）が得られるまで待ち、ステップＳＰ２において複数の電流素片のそれぞれの大きさに対応する直径の円を割り当て、ステップＳＰ３において生体断層像を表示し、ステップＳＰ４において、割り当てられた円を対応箇所に生体断層像とオーバーラップした状態で表示し、ステップＳＰ５において興奮電流表示の終了が指示されたか否かを判別し、終了が指示されていない場合には、ステップＳＰ６において異なる時点における電流素片の位置および大きさが得られるまで待ってから再びステップＳＰ２の処理を行なう。逆に、ステップＳＰ５において終了が指示された場合にはそのまま一連の処理を終了する。但し、ステップＳＰ２における円の割り当てについては、電流素片の大きさに正確に対応する直径の円を割り当てるようにしてもよいが、電流素片の大きさを複数段階に区分し、各区分に対応して段階的に変化するように円の直径を割り当ててもよい。

【００７０】

【実施例８】図２０はこの発明の生体磁場測定測結果表示方法の他の実施例を説明するフローチャートであり、ステップＳＰ１において、生体断層像に対応する平面内における臓器等の存在箇所が検出されるまで待ち、ステップＳＰ２において臓器等の存在箇所に対応して所定の直径の通常の円を割り当て、ステップＳＰ３において上記平面内における、所定の時点における電流素片の位置および大きさが得られるまで待ち、ステップＳＰ４において、該当する円に代えて複数の電流素片のそれぞれの大きさに対応する直径の強調表示円を割り当て、ステップＳＰ５において生体断層像を表示し、ステップＳＰ６において、割り当てられた円を対応箇所に生体断層像とオーバーラップした状態で表示し、ステップＳＰ７において興奮電流表示の終了が指示されたか否かを判別し、終了が指示されていない場合には、ステップＳＰ８において異なる時点における電流素片の位置および大きさが得られるまで待ってから再びステップＳＰ４の処理を行なう。逆に、ステップＳＰ７において終了が指示された場合にはそのまま一連の処理を終了する。

【００７１】図２１はこの実施例による興奮電流の表示例を示す図であり、著しく高い視認性を発揮できていることが分る。また、興奮電流が存在していない箇所においても臓器等に対応して通常の円が表示されているとともに、円同士の間にはかなりの間隙が存在し、この間隙を通して断層像を簡単に確認できる。特に、時系列的に興奮電流を表示する場合には、例えば最大の興奮電流が変化する状態を簡単に把握できることになる。

【００７２】

【実施例９】図２２はこの発明の生体磁場測定結果表示方法のさらに他の実施例を説明するフローチャートであり、ステップＳＰ１において所定の時点における電流素片の位置および大きさが得られるまで待ち、ステップＳＰ２において複数の電流素片のそれぞれの大きさに対応する直径の球を割り当て、ステップＳＰ３において生体構造参照像を３次元的に半透明表示し、ステップＳＰ４において、割り当てられた球を対応箇所に生体構造参照像とオーバーラップした状態で表示し、ステップＳＰ５において興奮電流表示の終了が指示されたか否かを判別し、終了が指示されていない場合には、ステップＳＰ６において異なる時点における電流素片の位置および大きさが得られるまで待ってから再びステップＳＰ２の処理を行なう。逆に、ステップＳＰ５において終了が指示された場合にはそのまま一連の処理を終了する。

【００７３】したがって、この実施例の場合には、３次元的な生体構造参照像に対応付けて電流素片の大きさに対応する直径の球を表示でき、時系列的に球の表示を行なうことにより興奮電流の３次元的な伝播方向を簡単に把握できることになる。

【００７４】

【実施例１０】図２３はこの発明の生体磁場測定結果表示装置の一実施例を示すブロック図であり、電流素片解析結果を保持する解析結果保持部６００と、電流素片の大きさに対応する直径の円を割り当てる円割り当て部７００と、生体断層像を表示する断層像表示部８００と、断層像とオーバーラップさせた状態で割り当てられた直径の円を表示する円表示部９００とを有している。

【００７５】したがって、生体断層像の表示とオーバーラップさせて電流素片の大きさに対応する円を表示でき、興奮電流の視認性を著しく高めることができる。そして、時系列的に解析結果に基づいて円のオーバーラップ表示を行なうことにより興奮電流の伝播方向を簡単に把握できる。尚、上記実施例７～１０において、例えば、生体像の視認性の多少の低下を許容できる場合には、円に代えて正方形、球に代えて立方体を表示することが可能であるほか、この発明の要旨を変更しない範囲内において種々の設計変更を施すことが可能である。

【００７６】

【発明の効果】以上のように請求項１の発明は、所定間隔毎の断層像しか得られていなくても、補間演算を行なうことにより全空間に対応して立体像データを得、しかも区分された小立体領域に含まれる立体像データの数に基づいて小立体領域を２値化することにより単純化され

た立体像を得ることができ、ひいては、可視的に表示した場合に、臓器等に相当する箇所、空間に相当する箇所を簡単に認識できるという特有の効果を奏する。

【００７７】請求項２の発明も、所定間隔毎の断層像しか得られていなくても、補間演算を行なうことにより全空間に対応して立体像データを得、しかも区分された小立体領域に含まれる立体像データの数に基づいて小立体領域を２値化することにより単純化された立体像を得ることができ、ひいては、可視的に表示した場合に、臓器等に相当する箇所、空間に相当する箇所を簡単に認識できるという特有の効果を奏する。

【００７８】請求項３の発明は、複数のビオ・サバールの法則の演算結果の累積加算値が磁場計測値と高精度に近似されるまで補正を行なうことにより、各小立体領域の頂点における磁場源情報を得ることができ、全体として処理負荷を大幅に低減できるという特有の効果を奏する。請求項４の発明は、互に近接する状態で割り当てられた、大きさが互に等しくかつ向きが互に逆の磁場源ベクトルが存在していても、これらを確実に補正でき、一層高精度に推定された磁場源情報を得ることができるとともに、隣接する頂点間で再配分を行なうことにより推定を行なうのであるから、推定対象となる磁場源情報の数に見合って従来必要とされていた測定点数よりも少ない測定点に基づいて高精度の磁場源推定を達成できるという特有の効果を奏する。

【００７９】請求項５の発明も、複数のビオ・サバールの法則の演算結果の累積加算値が磁場計測値と高精度に近似されるまで補正を行なうことにより、各小立体領域の頂点における磁場源情報を得ることができ、全体として処理負荷を大幅に低減できるという特有の効果を奏する。請求項６の発明も、互に近接する状態で割り当てられた、大きさが互に等しくかつ向きが互に逆の磁場源ベクトルが存在していても、これらを確実に補正でき、一層高精度に推定された磁場源情報を得ることができるとともに、隣接する頂点間で再配分を行なうことにより推定を行なうのであるから、推定対象となる磁場源情報の数に見合って従来必要とされていた測定点数よりも少ない測定点に基づいて高精度の磁場源推定を達成できるという特有の効果を奏する。

【００８０】請求項７の発明は、生体構造参照像を表示するとともに、生体構造参照像の該当位置に設定されたサイズの単位図形を表示するのであるから、矢印の方向と長さで物理量計測結果を表示する場合と比較して、例えば、最大の生体物理量計測結果の分布状態を簡単に認識できるとともに、生体物理量計測結果を動的に表示することにより、例えば、最大の生体物理量計測結果の分布状態の時間的変動を簡単に認識できるという特有の効果を奏する。

【００８１】請求項８の発明は、請求項７の効果に加え、単位図形が円であるから、単位図形同士の隙間をかなり大きくでき、背景となる生体構造参照像の把握が容易になるという特有の効果を奏する。請求項９の発明は、生体構造参照像を表示するとともに、生体構造参照像の該当位置に設定されたサイズの単位図形を表示するのであるから、矢印の方向と長さで物理量計測結果を表示する場合と比較して、例えば、最大の生体物理量計測結果の分布状態を簡単に認識できるとともに、生体物理量計測結果を動的に表示することにより、例えば、最大の生体物理量計測結果の分布状態の時間的変動を簡単に認識できるという特有の効果を奏する。

【００８２】請求項１０の発明は、請求項９の効果に加え、単位図形が円であるから、単位図形同士の隙間をかなり大きくでき、背景となる生体構造参照像の把握が容易になるという特有の効果を奏する。

【図面の簡単な説明】

【００８３】

【図１】この発明の断層像処理方法の一実施例を説明するフローチャートである。

【００８４】

【図２】断層像の一例を示す概略図である。

【００８５】

【図３】表示立方体と非表示立方体との割り当て状態を概略的に示す平面図である。

【００８６】

【図４】図３に対応する斜視図である。

【００８７】

【図５】この発明の断層像処理装置の一実施例を示すブロック図である。

【００８８】

【図６】この発明の生体磁場測定装置の一実施例を示すブロック図である。

【００８９】

【図７】この発明の生体磁場測定装置の他の実施例を示すブロック図である。

【００９０】

【図８】１つの階層型パーセプトロンに対応する部分の構成を詳細に示す概略図である。

【００９１】

【図９】この発明の生体磁場測定方法のさらに他の実施例を示すブロック図である。

【００９２】

【図１０】この発明の磁場源測定装置のさらに他の実施例を示すブロック図である。

【００９３】

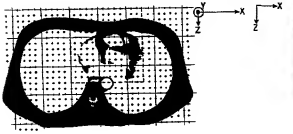
【図１１】推定されている電流素片のベクトル成分の再配分対象となる隣接頂点を抽出する処理を説明する概略図である。

【００９４】

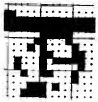
【図１２】再配分による電流素片の推定処理を説明する概略図である。

【００９５】
【図１３】ＭＲＩ画像に基づいて得られた深さが６cmの頂点情報を示す図である。
【００９６】
【図１４】Ｒ波出現前３５msecに対応する推定結果を示す図である。
【００９７】
【図１５】Ｒ波出現前３３msecに対応する推定結果を示す図である。
【００９８】
【図１６】Ｒ波出現前３０msecに対応する推定結果を示す図である。
【００９９】
【図１７】Ｒ波出現前２５msecに対応する推定結果を示す図である。
【０１００】
【図１８】Ｒ波出現前２０msecに対応する推定結果を示す図である。
【０１０１】
【図１９】この発明の生体磁場測定結果表示方法の一実施例を説明するフローチャートである。
【０１０２】
【図２０】この発明の生体磁場測定結果表示方法の他の実施例を説明するフローチャートである。
【０１０３】
【図２１】図２０の実施例による興奮電流の表示例を示す図である。
【０１０４】
【図２２】この発明の生体磁場測定結果表示方法のさらに他の実施例を説明するフローチャートである。
【０１０５】
【図２３】この発明の生体磁場測定結果表示装置の一実施例としての興奮電流表示装置を示すブロック図である。
【０１０６】
【符号の説明】
３　断層像補間部　　７　立方体割り当て部　　８　画素数計数部
９　判別部　　１０　表示立方体割当部　　２０，２００　シグマ・ユニット
３０，３００　誤差演算器　　４１ｉ　修正量算出部
４２ｉ　頂点抽出部
４３ｉ　正規化部　　４４ｉ　再配分比率算出部　　４５ｉ　再配分部
４６ｉ　推定値更新部　　４０，５００　情報収集ユニット
１０１，１０２，・・・，１０ｍ　階層型パーセプトロン
１１１，１１２，・・・，１１ｍ　ビオ・サバール演算ユニット
１１１ａ，１１２ａ，・・・，１１ｍａ，１２１，１２２，・・・，１２ｍ　補正部
７００　円割り当て部　　８００　断層像表示部
９００　円表示部

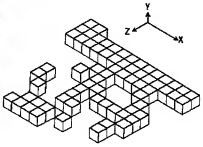
【図２】



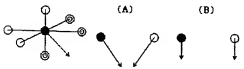
【図３】



【図４】

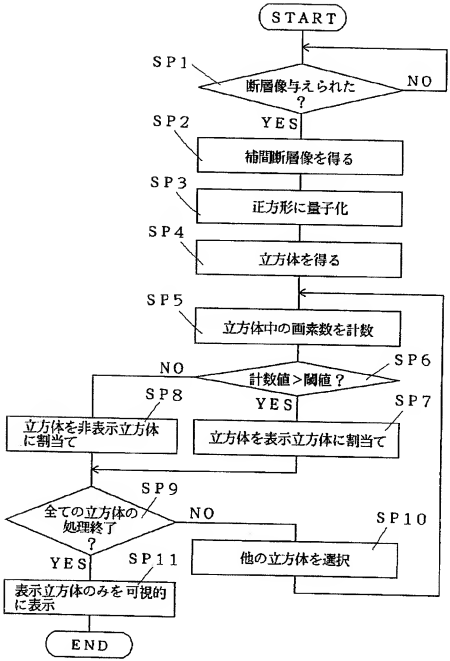


【図１１】

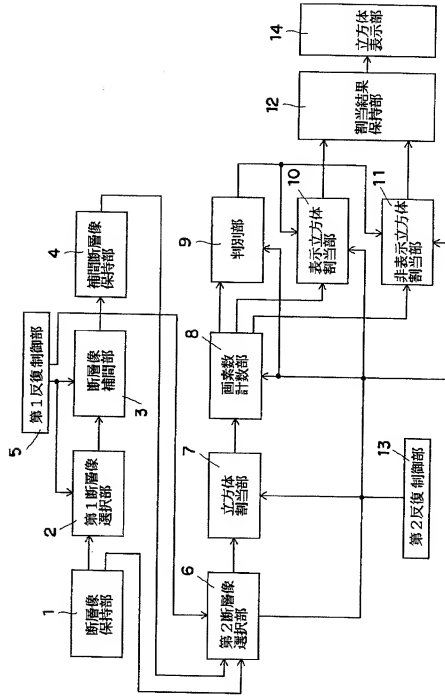


【図１２】

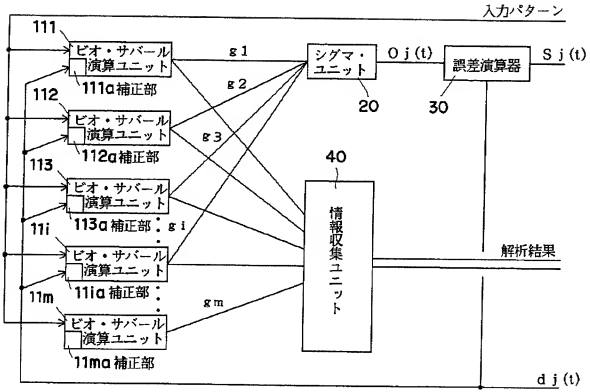
【図1】


START
SP1
断層像与えられた？
NO
YES
SP2
補間断層像を得る
SP3
正方形に量子化
SP4
立方体を得る
SP5
立方体中の画素数を計数
SP6
計数値＞閾値？
NO
YES
SP8
立方体を非表示立方体に割当て
SP7
立方体を表示立方体に割当て
SP9
全ての立方体の処理終了？
NO
YES
SP10
他の立方体を選択
SP11
表示立方体のみを可視的に表示
END

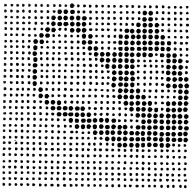
【図5】


1
断層像保持部
2
第1断層像選択部
3
断層像補間部
4
補間断層像保持部
5
第1反復制御部
6
第2断層像選択部
7
立方体割当部
8
画素数計数部
9
判別部
10
表示立方体割当部
11
非表示立方体割当部
12
割当結果保持部
13
第2反復制御部
14
立方体表示部

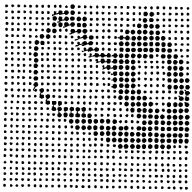
【図６】



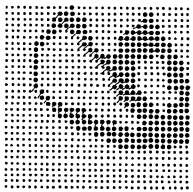
【図１３】



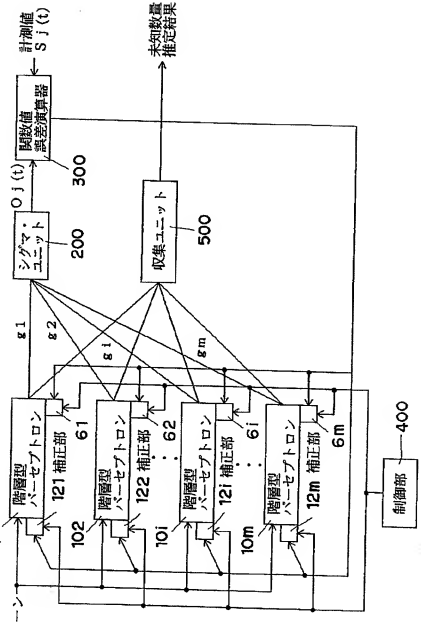
【図１４】



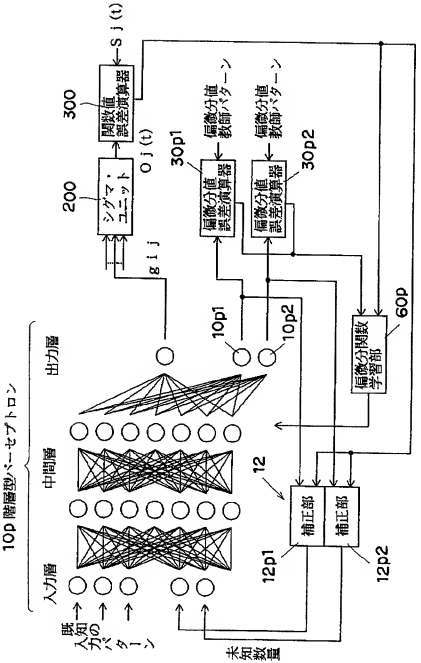
【図１５】



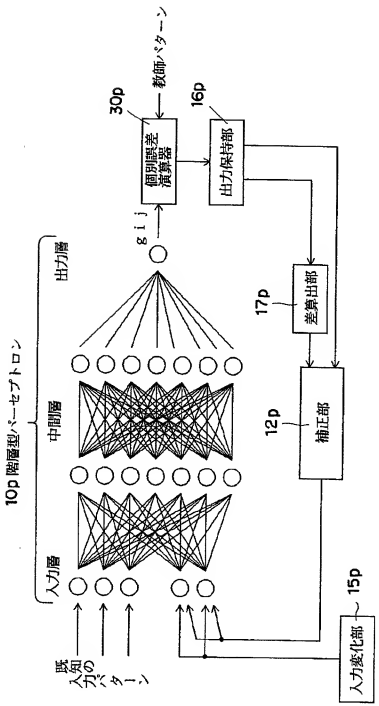
【図7】


入力パターン
101
階層型パーセプトロン
121 補正部
61
102
122 補正部
62
10i
12i 補正部
6i
10m
12m 補正部
6m
制御部
400
g1
g2
gi
gm
シグマ・ユニット
200
Oj(t)
関数値誤差演算器
300
計測値 Sj(t)
収集ユニット
500
未知数値推定結果

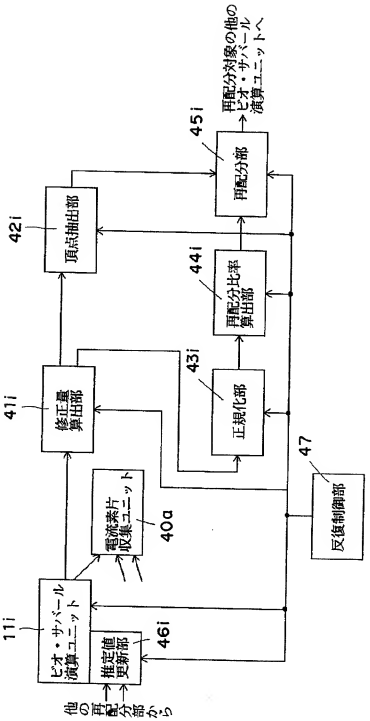
【図8】


10p 階層型パーセプトロン
入力層
中間層
出力層
既知の入力パターン
未知数量
gij
Oj(t)
Sj(t)
200
シグマ・ユニット
300
閾数値誤差演算器
30p1
偏微分値誤差演算器
偏微分値教師パターン
30p2
偏微分値誤差演算器
偏微分値教師パターン
10p1
10p2
12
12p1
補正部
補正部
12p2
偏微分閾数学習部
60p

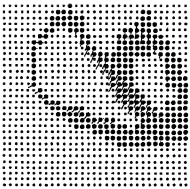
【図9】


10p 階層型パーセプトロン
入力層
中間層
出力層
既知の入力パターン
15p
入力変化部
12p
補正部
17p
差異出部
16p
出力保持部
30p
個別誤差演算器
教師パターン
g i j

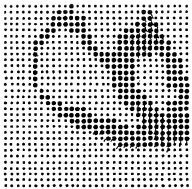
【図10】


他の再配分部から
11i
ビオ・サンパール演算ユニット
推定値更新部
46i
41i
修正量算出部
電波素片収集ユニット
40a
42i
頂点抽出部
43i
正規化部
44i
再配分比率算出部
45i
再配分部
再配分対象の他のビオ・サンパール演算ユニットへ
47
反復制御部

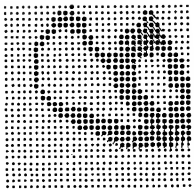
【図16】



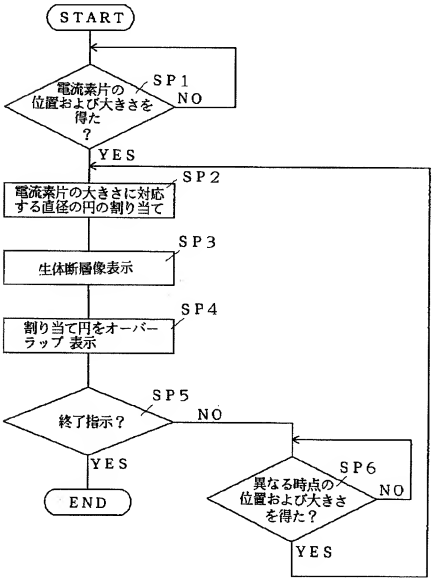
【図17】



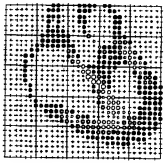
【図18】



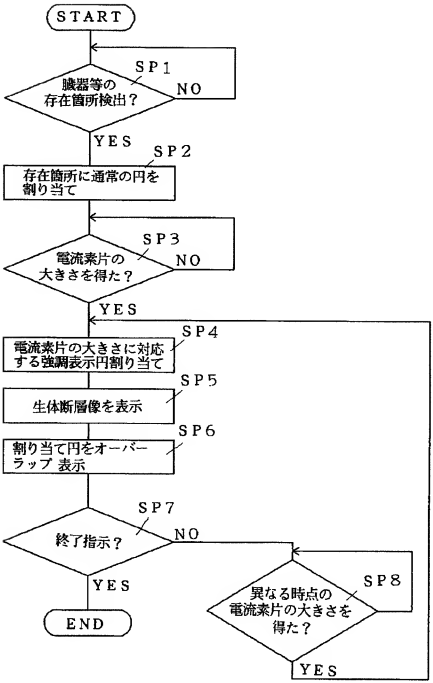
【図19】



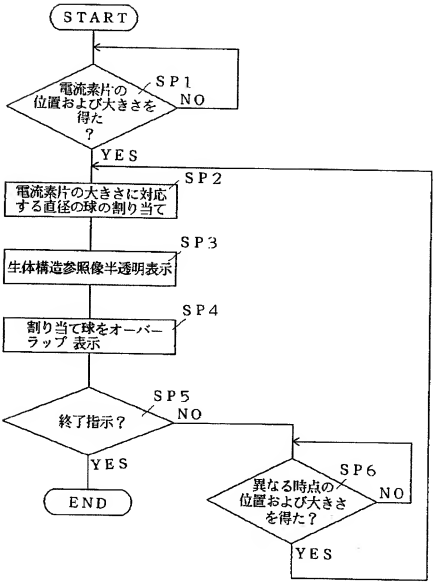
【図21】



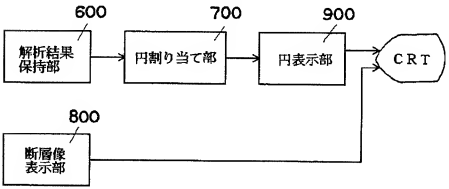
【図20】


START
SP1
臓器等の
存在箇所検出？
NO
YES
SP2
存在箇所に通常の円を
割り当て
SP3
電流素片の
大きさを得た？
NO
YES
SP4
電流素片の大きさに対応
する強調表示円割り当て
SP5
生体断層像を表示
SP6
割り当て円をオーバー
ラップ 表示
SP7
終了指示？
NO
YES
END
SP8
異なる時点の
電流素片の大きさを
得た？
YES

【図22】


START
電流素片の位置および大きさを得た？
SP1
NO
YES
電流素片の大きさに対応する直径の球の割り当て
SP2
生体構造参照像半透明表示
SP3
割り当て球をオーバーラップ表示
SP4
終了指示？
SP5
NO
YES
END
異なる時点の位置および大きさを得た？
SP6
NO
YES

【図23】


600
解析結果保持部
700
円割り当て部
900
円表示部
CRT
800
断層像表示部